TRANSACTIONS

OF

THE FEDERATED INSTITUTION

OF

MINING ENGINEERS.

VOL. VIII.—1894-95.

EDITED BY M. WALTON BROWN, SECRETARY.

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The Institution is not responsible, as a body, for the statements, facts, and opinions advanced in any of its publications.

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TRANSACTIONS

OF

THE FEDERATED INSTITUTION

OF

MINING ENGINEERS.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
AUGUST 4TH, 1894.

MR. A. L. STEAVENSON, RETIRING PRESIDENT, IN THE CHAIR.

THE LATE MR. T. H. M. STRATTON.

The following letter was read:—

CRAMLINGTON HOUSE, NORTHUMBERLAND,
JULY 7TH, 1894.

DEAR SIR,—Will you express, to the Council of The North of England Institute of Mining and Mechanical Engineers, my sincere thanks for their kind sympathy and condolence with me and my children in our sad bereavement and terrible grief. My dear husband valued his privilege of membership in your Institute, and often wished that he had possessed more time and ability to further its interests.

I am, dear Sir,
Yours faithfully,
KATHLEEN HELEN STRATTON.

M. Walton Brown, Esq.

The SECRETARY read the minutes of the last General Meeting and reported the proceedings of the Council at their meetings on July 21st and that day.

ELECTION OF OFFICERS.

The PRESIDENT appointed Messrs. J. T. Todd, A. M. Potter, W. E. Nicholson, and Luke Thursby as scrutineers of the balloting papers for the election of officers for the year 1894-95. These gentlemen afterwards reported the result of the ballot as follows:—

PRESIDENT.

Mr. T. DOUGLAS.

VICE-PRESIDENTS.

Mr. W. ARMSTRONG.
Mr. T. W. BENSON.
Mr. W. F. HALL.
Mr. J. L. HEDLEY.
Mr. GEORGE MAY.
Mr. J. G. WEEKS.

COUNCIL.

Mr. W. ARMSTRONG, Jun.
Mr. T. W. ASQUITH.
Mr. W. C. BLACKETT.
Mr. T. FORSTER BROWN.
Mr. T. E. FORSTER.
Mr. W. H. HEDLEY.
Mr. T. HEPPELL.
Mr. H. LAWRENCE.
Mr. C. C. LEACH.
Sir W. T. LEWIS.
Prof. J. H. MERIVALE.
Mr. H. PALMER.
Mr. A. M. POTTER.
Mr. H. RICHARDSON.
Mr. R. ROBINSON.
Mr. T. O. ROBSON.
Mr. SIMON TATE.
Mr. W. O. WOOD.

Mr. DOUGLAS thanked the members for the compliment they had paid him in electing him as the President for the ensuing year. He had considerable hesitation in accepting the office, not from any want of desire, but anxiety that everything should be done for the interests of the Institute, and from the fact that his health had been lately of a somewhat precarious character. Associated as he had always been with the Institute from the first meeting in 1852, however, he thought it was his duty to accept the office, knowing that he would have the consideration of all the members of the Institute, and that the Council of the Institute would assist him in every possible way. He moved that a very hearty vote of thanks be accorded to Mr. Steavenson for his services in the Presidential chair during the past year. He had known the President personally perhaps longer than any other member present, and it was a pleasure to him to

propose this vote, as Mr. Steavenson had devoted an amount of time and energy to the Institute, not only this year, because he happened to be the President, but during the whole of the very long time that he had been connected with the Institute.

Mr. W. C. BLACKETT seconded the resolution, which was carried with acclamation.

The CHAIRMAN, in acknowledging the vote of thanks, said he was sorry that circumstances over which he had no control had perhaps prevented him from carrying out the duties of the position as he would have liked; however, they might be sure he would continue to do all that he could to promote the interests of the Institute.

Mr. J. T. TODD moved, and the CHAIRMAN seconded, that a hearty vote of thanks be accorded to the Vice-Presidents and to the members of the Council for their valuable services during the past year.

The motion was agreed to.

The CHAIRMAN moved, and Mr. BLACKETT seconded, that a vote of thanks be accorded to the scrutineers for their services, which was agreed to.

The Annual Reports of the Council and of the Finance Committee were read as follows:—

ANNUAL REPORT OF THE COUNCIL.

The continued increase in the number of the membership during recent years is shown in the following table:—

	August 1st.		
	1892.	1893.	1894.
Honorary Members...	24	25	26
Members	545	565	624
Associate Members...	35	47	53
Associates	34	47	68
Students	35	34	20
Subscribing Collieries	18	22	22
Totals	691	740	813

One hundred and nineteen members of all classes have joined the Institute during the year, and after allowing for the losses, through death, resignations, and non-payment of subscription, the net increase is 73. The members may be congratulated upon the increasing prosperity of the Institute, and the Council desire them, at all times, to promote its claims and advantages, and to extend the membership.

The Explosives Committee have carried on investigations at the experimental station, and they anticipate being able to issue the report upon "flameless explosives" in presence of gas, before the end of the year. The appliances and apparatus were inspected by several of the members of the Royal Commission on Explosions from Coal-dust in Mines, who expressed great satisfaction with the experiments and results obtained by the committee.

The "Report of the Prussian Fire-damp Commission," translated by Dr. P. P. Bedson and Mr. L. L. Belinfante; and "Mining Explosives: Their Definition as Authorized under the Explosives Act (1875)," by Mr. A. C. Kayll, have been of great use to the Committee. The papers on "A Contribution to our Knowledge of Coal-dust," by Dr. P. P. Bedson and Mr. W. McConnell, and on "The Combustion of Oxygen and Coal-dust in Mines," by Mr. W. C. Blackett, will also be of value when explosives are tested in presence of coal-dust. Mr. J. D. Kendall's paper on "Miss-fires" confirms some of the results obtained and the practice of the Committee in their experiments.

The library has been maintained in an efficient condition during the year. The additions by donations, exchange, and purchase have been :—

Bound volumes	265
Pamphlets, reports, etc.	245
A total of	510 titles.

And there are now at least 6,666 volumes and 1,267 unbound pamphlets, etc., in the library. Owing to this large increase, bookshelves have been placed in the corridor adjacent to the lecture-theatre, and ample space has been thus obtained for further additions to the library.

The Wood Memorial Hall, lecture theatre, etc., are now lighted by electricity, which has materially added to the convenience of these rooms.

The Watson collection of mining-plans and papers has been placed in the corridor, where they may be examined, but not removed, by members.

The reservation of a reading-room has been under consideration, and the Council request the views of members upon the question.

The fifth volume (S—T) of the "Sinkings and Borings" has been completed, and may be purchased by the members. The Council trust that the remaining volumes will be issued at early dates.

Members who desire to complete their sets of the *Transactions* and other publications of the Institute may now do so at the recently revised prices.

The files of some of the *Transactions* of societies in the library are incomplete owing to loss of volumes or parts, and it is desired that members will return the missing volumes.*

The value of the library would be materially increased if members and friends would kindly present books, maps, etc., which can be spared from their own libraries.

The Federated Institution of Mining Engineers has now been in existence for five years, and during the last year general meetings have been held at Glasgow on September 5th, 6th, and 7th, 1893; at Leeds on February 14th, 15th, and 16th, 1894; and at London on June 7th, 8th, and 9th, 1894. The meetings have been well attended, and the status of the Institution enhanced by the papers communicated and the accompanying discussions. With continued energy on the part of the Federated Institutes, The Federated Institution of Mining Engineers should include the whole of the societies interested in mining and metallurgical engineering.

The report of the committee on mechanical ventilators is approaching completion, and will, it is hoped, be issued during the current year to the members.

The Council have requested Prof. J. H. Merivale to represent the Institute at the conference of delegates of corresponding societies at the ensuing meeting of the British Association for the Advancement of Science at Oxford.

Prizes of books have been awarded to the writers of the following papers, communicated to the Institute during the year 1892-93:—

"Use of Cement in Shaft-sinking." By Mr. Bennett H. Brough.

"Observations on Fans of Different Types Working on the same Upcast Shaft." By the Rev. G M. Capell.

"Manometric Efficiency of Fans." By the Rev. G. M. Capell.

"The Choice of Coarse and Fine-crushing Machinery and Processes of Ore Treatment." By Mr. A. G. Charleton.

* See list accompanying the Annual Report of the Council for 1892.

"Steam Boilers with Forced Blast: the Perrett System for Burning Dust and Rejected Fuels; with Notes on Testing Boilers." By Mr. Bryan Donkin, Jun.

"The Gold-bearing Veins of the Organos District, Tolima, U.S. Colombia." By Mr. Edward Halse.

"The Education of Mining Engineers." By Prof. J. H. Merivale.

"The Geology and Coal-deposits of Natal." By Mr. R. A. S. Redmayne.

"Gold-mining in Brazil." By Mr. E. M. Touzeau.

The papers communicated to the Institute have been:—

"A Contribution to our Knowledge of Coal-dust, Part II." By Dr. P. Phillips Bedson, D.Sc. (Lond.).

"A Contribution to our Knowledge of Coal-dust, Part III." By Dr. P. Phillips Bedson, D.Sc. (Lond.), and Mr. W. McConnell, Jun.

"The Combustion of Oxygen and Coal-dust in Mines." By Mr. W. C. Blackett.

"History and Description of the Greenside Silver-lead Mine, Patterdale." By Mr. W. H. Borlase.

"The Choice of Coarse and Fine-crushing Machinery and Processes of Ore Treatment." By Mr. A. G. Charleton.

"The Ghorband Lead-mines, Afghanistan." By Mr. A. L. Collins.

"Note on the Antimony Deposit of El Altar, Sonora, Mexico." By Mr. Edward Halse.

"Note on the Occurrence of Mercury at Quindiú, Tolima, U.S. Colombia." By Mr. Edward Halse.

"Description of the Whitehaven Collieries." By Mr. H. M. James.

"Mining Explosives: Their Definition as Authorized under the Explosives Act (1875)." By Mr. A. C. Kayll.

"Miss-fires." By Mr. J. D. Kendall.

"A Short Description of the Hæmatite Deposit worked by the Salter, Eskett, and Winder Gill Mines, and the Method of Working It." By Mr. J. D. Kendall.

"Singareni Coal-field, Hyderabad, India." By Mr. J. P. Kirkup.

"Corliss-engined Fan at Seghill Colliery." By Mr. C. C. Leach.

"Historical Sketch of the Whitehaven Collieries." By Mr. R. W. Moore.

"Description of the St. Helens Colliery, Workington." By Mr. G. Scoular.

"Presidential Address." By Mr. A. L. Steavenson.

"Magnetic Declination and its Variations." By Prof. H. Stroud.

"Minerals and Mining in Tasmania." By Mr. A. P. Wilson.

The Council congratulate the members on the success of the general meeting recently held in Cumberland and Westmorland, and consider

that the best thanks of the Institute are due to the committee who made the arrangements. The Council also direct the attention of the members to the great courtesy shown by the Whitehaven Collieries Company, the Postlethwaites Eskett Mining Company, the Cleator Iron-ore Company, the Winder Gill Iron-ore Company, the St. Helens Colliery and Brickworks Company, and the Greenside Mining Company, and have great pleasure in recording the thanks of the Institute to all who by their services contributed to the holding of that successful meeting.

FINANCE REPORT.

The ordinary income for the year 1893-94 amounted to £1,898 4s. 7d., being an increase over the previous year of £86 10s. 4d.

The total receipts from subscriptions and arrears, excluding amounts paid in advance, amounted to £1,567 9s., an increase of £106 18s. over the preceding year.

The amount of subscriptions now in arrear, after striking off those which are considered irrecoverable and excluding the current year, is £29 8s.

The total expenditure amounted to £1,909 16s. 8d., an increase of £177 1s. 2d. The exceptional items contributing to this increase are: Contributions to The Federated Institution of Mining Engineers, owing to the increased number of members, £55 14s. 5d.; electric light fittings in the Wood Memorial Hall and Lecture Theatre, £57; book-shelves in the corridor adjoining the Lecture Theatre, £87 4s.; and an increase on account of postages of £12 0s. 3d., due to the increased number of members. There has, however, been a decrease of £29 1s. 4d. in the expenditure on books for the library, and of £18 18s. on the amount awarded for prizes, owing to last year's balance sheet, including the prizes awarded for two years.

The CHAIRMAN proposed the adoption of the Reports of the Council and of the Finance Committee.

Mr. THOMAS DOUGLAS seconded the resolution.

The resolution was then agreed to.

DR. THE TREASURER IN ACCOUNT WITH THE NORTH OF ENGLAND

FOR THE YEAR ENDING

			£ s. d.	£ s. d.
July 22nd, 1893.				
To Balance at Bankers			468 3 8	
" " in Treasurer's hands			84 12 3	
" Outstanding Amounts for Authors' Excerpts			11 15 4	
				564 11 3
" Dividend of 7½ per cent. on 134 Shares of £20 each in the Institute and Coal Trade Chambers Co., Ltd., for the year ending June, 1894			201 0 0	
" Interest on Investments with the River Tyne Commissioners			53 8 0	
				254 8 0
To SUBSCRIPTIONS FOR 1893-94 AS FOLLOWS:—				
466 Members	@ £2 2s.		978 12 0	
33 Associate Members	@ £2 2s.		69 6 0	
41 Associates	@ £1 1s.		43 1 0	
26 Students	@ £1 1s.		27 6 0	
87 New Members	@ £2 2s.		182 14 0	
1 New Member	.. ...		25 0 0	
10 New Associate Members	@ £2 2s.		21 0 0	
15 New Associates	@ £1 1s.		15 15 0	
5 New Students	@ £1 1s.		5 5 0	
			1,367 19 0	
To SUBSCRIBING COLLIERIES, VIZ.:—				
Ashington Coal Company		£2 2 0		
Birtley Iron Company		6 6 0		
Bridgewater Trustees		6 6 0		
Marquis of Bute		2 2 0		
Butterknowle Colliery Company ...		2 2 0		
Cowpen Coal Company		4 4 0		
Earl of Durham		10 10 0		
Elswick Coal Company		2 2 0		
Haswell Coal Company		4 4 0		
Hetton Coal Company		10 10 0		
Hutton Henry Coal Company		2 2 0		
Marquess of Londonderry		10 10 0		
North Brancepeth Coal Company ...		2 2 0		
North Hetton Coal Company		6 6 0		
Ryhope Coal Company		4 4 0		
Seghill Coal Company		2 2 0		
South Hetton Coal Company		4 4 0		
Stella Coal Company		2 2 0		
Throckley Coal Company		2 2 0		
Victoria Garesfield		2 2 0		
Wearmouth Coal Company		4 4 0		
Westport Coal Company		4 4 0		
			96 12 0	
To Donations			4 4 0	
			1,468 15 0	
Less—Subscriptions for current year paid in advance last year			57 15 0	
			1,411 0 0	
To Arrears received			156 9 0	
			1,567 9 0	
" Subscriptions paid in advance during current year ...			56 14 0	
				1,624 3 0
" Sale of Publications				19 13 7
				£2,462 15 10

INSTITUTE OF MINING AND MECHANICAL ENGINEERS. CR.
JULY 31ST, 1894.

	£ s. d.	£ s. d.
July 21st, 1894.		
By Printing and Stationery		160 2 7
„ Books for Library	44 19 11	
„ Prizes for Papers	17 17 0	
„ Incidental Expenses	54 1 10	
„ Postages	57 5 5	
„ Sundry Accounts	16 17 6	
„ Travelling Expenses	7 6 1	
„ Salaries	150 0 0	
„ Clerks' Wages	152 7 4	
„ Reporter's Salary	12 12 0	
„ Rent	93 7 2	
„ Rates and Taxes	22 2 10	
„ Insurance	12 8 4	
„ Furnishing, Repairs, etc.	107 19 3	
„ Coals, Gas, Electric Light, and Water	21 3 1	
„ Electric Light and Fittings, etc.	57 0 0	
		827 7 9
„ Fan Committee	1 14 9	
„ Explosives Committee	81 16 1	
„ British Association Meeting—Delegate's Expenses ...	6 17 0	
		90 7 10
By Federated Institution of Mining Engineers—Subscriptions	847 10 3	
Less—Amounts paid by Authors for Excerpts ...	15 11 9	
		831 18 6
		1,909 16 8
By Balance at Bank	457 10 0	
„ „ in Treasurer's hands	84 12 3	
„ Outstanding Amounts for Authors' Copies	10 16 11	
		552 19 2
		£2,462 15 10

I have examined the above account with the Books and Vouchers relating thereto, and certify that, in my opinion, it is correct.

JOHN G. BENSON,
CHARTERED ACCOUNTANT.

Newcastle-upon-Tyne,
August 3rd, 1894.

DR. THE TREASURER IN ACCOUNT

			£	s.	d.	£	s.	d.
To 565 Members, 24 of whom are Life Members.								
541	541	@ £2 2s.				1,136	2	0
To 47 Associate Members, 5 of whom are Life Members.								
42	42	@ £2 2s.				88	4	0
To 47 Associates		@ £1 1s.				49	7	0
To 34 Students, 1 transferred to list of Members.								
33	33	@ £1 1s.				34	13	0
To 22 Subscribing Collieries		... ...				96	12	0
To 87 New Members		@ £2 2s.				182	14	0
To 1 New Member		@ £25				25	0	0
To 10 New Associate Members		@ £2 2s.				21	0	0
To 15 New Associates		@ £1 1s.				15	15	0
To 5 New Students		@ £1 1s.				5	5	0
To Donations						4	4	0
						1,658	16	0
To Arrears, as per Balance Sheet 1892-93			220	10	0			
Add—Arrears considered irrecoverable, but since received			10	10	0			
			231	0	0			
Less—Struck off as irrecoverable. Arrears		£45 3 0						
„ „ „ Current year		27 6 0						
			72	9	0			
						158	11	0
						1,817	7	0
To Subscriptions Paid in Advance						56	14	0
						£1,874	1	0

WITH SUBSCRIPTIONS, 1893-94. CR.

		PAID. £ s. d.	UNPAID. £ s. d.
By 466 Members, paid	@ £2 2s.	978 12 0	......
By 74 „ unpaid	@ £2 2s.	......	155 8 0
By 1 „ dead	@ £2 2s.	......	2 2 0
541			
By 33 Associate Members, paid	@ £2 2s.	69 6 0	......
By 8 „ „ unpaid	@ £2 2s.	......	16 16 0
By 1 „ „ dead	@ £2 2s.	......	2 2 0
42			
By 41 Associates, paid	@ £1 1s.	43 1 0	......
By 6 „ unpaid	@ £1 1s.	......	6 6 0
47			
By 26 Students, paid	@ £1 1s.	27 6 0	......
By 7 „ unpaid	@ £1 1s.	......	7 7 0
33			
By 22 Subscribing Collieries, paid		96 12 0	......
By 87 New Members, paid	@ £2 2s.	182 14 0	......
By 1 New Member, paid	@ £25	25 0 0	......
By 10 New Associate Members, paid	@ £2 2s.	21 0 0	......
By 15 New Associates, paid	@ £1 1s.	15 15 0	......
By 5 New Students, paid	@ £1 1s.	5 5 0	......
By Donations		4 4 0	......
		1,468 15 0	190 1 0
Less struck off as irrecoverable		......	27 6 0
			162 15 0
By Arrears, paid		156 9 0	......
„ „ unpaid		......	29 8 0
By Subscriptions paid in advance		56 14 0	......
		1,681 18 0	192 3 0
			1,681 18 0
			£1,874 1 0

General Statement, July 21st, 1894.

Liabilities.

	£	s.	d.	£	s.	d.
Subscriptions paid in Advance during the year	56	14	0			
„ carried over from previous year	2	2	0			
				58	16	0
Capital				9,380	7	8
				£9,439	3	8

I have examined the above account with the books and vouchers relating thereto, and certify that, in my opinion, it is correct. The Share Certificates and Bonds have been produced to me.

JOHN G. BENSON,
Chartered Accountant.

Newcastle-upon-Tyne,
August 3rd, 1894.

Assets.

	£	s.	d.	£	s.	d.
Balance of Account at Bankers	457	10	0			
„ in Treasurer's hands	84	12	3			
Outstanding amounts for Authors' Excerpts ...	10	16	11			
				552	19	2
134 Shares of £20 each in the Institute and Coal Trade Chambers Co., Ltd.	......			2,680	0	0
Invested with River Tyne Commissioners ...	......			1,500	0	0
Arrears of Subscriptions	......			192	3	0
Value of 541 Bound Volumes of Transactions, @ 8s. 6d.	229	18	6			
„ 4,398 do., @ 6s....	1,319	8	0			
„ 2,565 Unbound Parts, @ 1s.	128	5	0			
„ 77 Copies of Mr. T. F. Brown's Map, @ 2s. 6d.	9	12	6			
„ 372 Copies of Index, Vols. 1-25, @ 1s.	18	12	0			
„ 848 Copies of Catalogue of Fossil, Plants, @ 2s. 6d.	106	0	0			
„ 752 Copies of Fossil Illustrations, @ 5s.	188	0	0			
„ 1,500 Copies of Borings and Sinkings (Vol. I. in Sheets) @ 1s.	75	0	0			
„ 270 Do., Vol. I., @ 2s. 6d.... ...	33	15	0			
„ 301 Do., Vol. II., @ 2s. 6d.... ...	37	12	6			
„ 314 Do., Vol. III., @ 2s. 6d.... ...	39	5	0			
„ 420 Do., Vol. IV., @ 2s. 6d.... ...	52	10	0			
„ 370 Do., Vol. V., @ 2s. 6d.... ...	46	5	0			
„ 254 Copies of Library Catalogue, @ 1s.	12	14	0			
„ 308 Copies of French Commission Report on Explosives in parts, @ 1s. ...	15	8	0			
„ 9 Do., Bound, @ 4s.	1	16	0			
				2,314	1	6
„ Office Furniture and Fittings ...	450	0	0			
„ Books and Maps in Library ...	1,750	0	0			
				2,200	0	0
				£9,439	3	8

REPRESENTATIVES ON THE COUNCIL OF THE FEDERATED INSTITUTION OF MINING ENGINEERS.

Mr. THOMAS DOUGLAS moved that the following gentlemen be elected as the representatives of this Institute on the Council of The Federated Institution of Mining Engineers for the ensuing year:—

Mr. E. BAINBRIDGE.	Mr. C. C. LEACH.
Mr. T. W. BENSON.	Sir WM. THOS. LEWIS.
Mr. THOS. J. BEWICK.	Mr. GEO. MAY.
Mr. W. C. BLACKETT.	Mr. H. PALMER.
Mr. T. FORSTER BROWN.	Mr. M. W. PARRINGTON.
Mr. WM. COCHRANE.	Mr. T. O. ROBSON.
Mr. JNO. DAGLISH.	Mr. J. B. SIMPSON.
Mr. G. B. FORSTER.	Mr. A. L. STEAVENSON.
Mr. T. E. FORSTER.	Mr. T. WRIGHTSON.
Mr. JEREMIAH HEAD.	Mr. LINDSAY WOOD.
Mr. HENRY LAWRENCE.	Mr. W. O. WOOD.

Mr. B. MCLAREN seconded the resolution, which was unanimously agreed to.

Mr. J. T. TODD moved that a vote of thanks be accorded to those gentlemen who had represented the Institute on the Council of The Federated Institution of Mining Engineers during the past year.

The CHAIRMAN seconded the resolution, which was cordially agreed to.

ALTERATION OF BYE-LAW 17.

The CHAIRMAN moved that Bye-law 17 be amended as follows:—

17. Any Member, Associate Member, Associate or Student may, at any time, compound for all future subscriptions by a payment in accordance with the following scale:—

Under 30	years of age,	the sum	of	£27
Over 30	„	„	„	24
„ 40	„	„	„	21
„ 50	„	„	„	18
„ 60	„	„	„	14

or on such other conditions as the Council may, in writing, accept. Every person so compounding shall be a Member, Associate Member, Associate or Student for life, as the case may be. Any Associate Member, Associate or Student so compounding who may afterwards be qualified to become a Member, may do so, by election in the manner described in Bye-law 8. All compositions shall be deemed capital money of the Institute.

Mr. THOMAS DOUGLAS seconded the resolution, which was unanimously adopted.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. R. HAY ANDERSON, Mining Engineer and Mine Manager, La Compañia Unida Mejicana de Minas, Guanajuato, Mexico.

Mr. HARRY ASHCROFT, Assistant Manager, Borrea Coal Co., Limited, Seetarampore, Bengal, India.

Mr. WILLIAM HENRY BORLASE, Mines Manager and Engineer, Brown How, Ulleswater, Glenridding, near Penrith.

Mr. IAN CAMERON, Mining Engineer, Sudbury, Ontario, Canada.

Mr. JAMES WILCOCKS CARRALL, Mining Engineer and Acting Commissioner of the Amoy Customs, Amoy, China.

Mr. HORATIO COLLINS, Manager of the Woodbush Gold Mining Co., Limited, Haenertsburg, Transvaal.

Mr. S. T. CROASDELL, Mechanical Engineer, Lowca Engineworks, Whitehaven.

Mr. GEORGE MATTHEW DARBY, General Manager of the Katrass Kerria Coal Co., Limited, Katrass P.O., *via* Barrakar, Bengal, India.

Mr. W. H. FURLONGE, Mining Engineer, c/o Messrs. Proctor Bros., Antananarivo, Madagascar.

Mr. STRANGEMAN HANCOCK, Mining Engineer, Rand Club, Johannesburg, Transvaal.

Mr. GUY ROCHE JOHNSON, Mining and Civil Engineer, Longdale, Alleghany Co., Virginia, U.S.A.

Mr. ROBERT KAY, Colliery Manager, South Tanfield, Stanley, R.S.O., Co. Durham.

Mr. JAS. MACNAB, Engineer, 17, Bolsover Street, Portland Place, London, W.

Mr. J. M. MAIN, Mining Engineer, Keekle House, Cleator Moor, *via* Carnforth.

Mr. JAMES MILLER, Chemist and Metallurgist, The Mexican Gold and Silver Recovery Co., P.O. Box 121, Mexico City, Republic of Mexico.

Mr. RALPH PATTERSON WILLIAM OSWALD, H.M. Inspector of Mines, 10, Rosebank, Whitehaven.

Mr. JOSEPH PROVIS, Lecturer on Mining, Metallurgy, and Technical Engineering, School of Mines, Kapunda, South Australia.

Mr. BEVERLEY S. RANDOLPH, Civil and Mining Engineer, Frostburg, Maryland, U.S.A.

Mr. WILLIAM REDSHAW, Colliery Manager, Whitehaven Colliery Office, Whitehaven.

Mr. WILLIAM SCHROLLER, Engineer and Contractor, 13, Old Elvet, Durham.

Mr. ELGIN SCOTT, Manager, Ropienka Oil-Wells, Ropienka, Galicia, Austria.

Mr. ARTHUR WHITCOMB SHEAFER, Mining Engineer and Geologist, Pottsville, Pennsylvania, U.S.A.

Mr. EDWARD THOMAS, Mine Surveyor, Mines Department, Sydney, New South Wales.

Mr. EDWARD WATSON, Colliery Manager, Redheugh Colliery, Gateshead.

Mr. C. L. WAUGH, Colliery Manager, Buckhill Collieries, Great Broughton, Cumberland.

ASSOCIATE MEMBERS—

Mr. ARTHUR D. CARR, Land Agent, Whickham Rectory, Whickham, R.S.O.

Mr. A. E. W. Gwyn, Agent of the Ingersoll-Sergeant Drill Co., 114a, Queen Victoria Street, London, E.C.

Mr. H. R. Hancock, Moonta Mines, South Australia.

Mr. George C. Hooper, Surveyor of Mines, Whitehaven Collieries, Whitehaven.

Mr. Stephen Humble, Jun., Engineer, 9, Victoria Street, Westminster, London, S.W.

Mr. Reiji Kanda, Mining Engineer, c/o Mr. Takahira Kanda, 9, Awajicho-Nichome, Kanda, Tokio, Japan.

Mr. C. Ochiltree Macdonald, Editor of the *Canadian Colliery Guardian*, 161, Hollis Street, Halifax, Nova Scotia.

Mr. Frank L. Nason, 5, Union Street, New Brunswick, New Jersey.

Mr. Frederick Danvers Power, c/o Messrs. Henderson & Macfarlane, 2, Bridge Street, Sydney, New South Wales.

Mr. Umfreville Percy Swinburne, Salisbury, Mashonaland, South Africa.

Students—

Mr. Cecil Alfred Burne, Mining Student, Cornsay Colliery Office, near Durham.

Mr. John Ridley Hetherington, Mining Student, Cornsay Colliery Office, near Durham.

Mr. William Jones, Mining Student, Trimdon Grange Colliery, Trimdon Grange, R.S.O.

Mr. Herbert William Middleton, Mining Student, Trimdon Grange Colliery, Trimdon Grange, R.S.O.

Mr. John William Peel, Mining Student, Coundon, Bishop Auckland.

The following gentlemen were nominated for election :—

Members—

Mr. William Henry Angove, Engineer, Albany, Western Australia.

Mr. James Ford Davison, Mining Engineer, Yarlside, Barrow-in-Furness.

Mr. Jonathan Dixon, Colliery Manager, Homeville, West Maitland, New South Wales.

Mr. John Thomas Foulis, Mine Agent, 42, Demesne Road, Douglas, Isle of Man.

Mr. George C. Hooper, Surveyor of Mines, Whitehaven Collieries, Whitehaven.

Mr. Henry Thornton Newbigin, Engineer and Manager, c/o Messrs. M. Coulson & Co., Spennymoor.

Mr. Horace Pratt, Colliery Manager, Jobs Hill, Crook.

Mr. James Russell, Mine Manager, etc., Ukalunda, via Bowen, Queensland.

Mr. Charles Turner Saner, General Manager, Van Ryn Estate and Gold Mining Co., Limited, P.O. Box 357, Johannesburg, Transvaal.

Mr. George A. Spotswood, Mining Engineer, 46, Clarence Street, Kingston, Ontario, Canada.

Mr. Thomas Pressick Yeoman, Mining Engineer, Bengal Coal Co., Giridih, Bengal, India.

Associate Members—

Mr. Benjamin Robinson Banyer, Mining Student, School of Mines, Kapunda, South Australia.

Mr. Edward Eccles, King Street, Newcastle-upon-Tyne.

Mr. Richard John Middleton, Manager of the *Mining Journal*, 18, Finch Lane, London, E.C., and The Lilies, Balfour Road, Highbury New Park, London, N.

Mr. B. J. Townsend, Toronto, Ontario, Canada.

Mr. Arthur Watson, Mining Student, Hamsterley Colliery, Ebchester, Co. Durham.

Mr. John Weatherburn, Draughtsman, 53, Cuthbert Street, Gateshead.

Associates—

Mr. Thomas Battey, Overman, Percy Terrace, Backworth Colliery.

Mr. William Ralph Bell, Assistant Under-manager. Wearmouth Colliery, Sunderland.

Mr. Joseph Stanley Cowell, Assistant Under-manager, Wearmouth Colliery, Sunderland.

Mr. Thomas Proctor, Overman, Ashington Colliery, Northumberland.

Mr. Jos. C. Southern, Master Wasteman, Harraton Colliery, Washington, R.S.O., Co. Durham.

Students—

Mr. Edward Herbert Clifford, Mining Student, 24, Gledstanes Road, West Kensington, London, S.W.

Mr. Michael Falcon, Mining Student, Thwaites Parsonage, Millom, Carnforth.

Mr. James Arthur Imeson, Articled Apprentice, Wearmouth Colliery, Sunderland.

Mr. Ernest McGowan, Articled Apprentice, Wearmouth Colliery, Sunderland.

Mr. H. G. Raeburn, Mining Student, Redheugh Colliery, Gateshead.

Mr. Frank Coulson read the following paper on "Sinking with Rock-drills":—

SINKING WITH ROCK-DRILLS.

By FRANK COULSON.

In the following paper, unless otherwise stated, it is understood that reference is made to a shaft 18 feet in diameter when finished.

In deciding the form of a shaft, the author fails to understand, why in some districts oblong shafts are sunk in preference to round ones, unless the object be to take out as little ground as possible. It seems desirable, in order to wind a given quantity of work, that there should be the same area (over and above the space occupied by the cages at meetings) in the one as in the other shaft, to admit of adequate ventilation. This consideration is in fact so important, that in many instances it is deemed desirable to sink a staple for a height of some 120 feet, having a holing into the shaft above and below meetings, so that the area for ventilation may not be diminished when the cages are passing each other.

An oblong shaft with the same area as one 18 feet in diameter should be about 24 feet long and 10 feet wide.

The following are some objections to an oblong as compared with a round shaft:—

(*a*) The cost of sinking is enhanced, owing to the difficulty of squaring out the corners.

(*b*) The cost of lining is more:—An oblong shaft lined with timber costs £2 5s. per foot; a round shaft lined with bricks at 20s. per 1,000 costs £1 4s. 2d. per foot.

(*c*) It is more difficult to shut off water in a square shaft.

(*d*) The difficulty of placing the shaft in the most suitable situation, having regard to surface and underground arrangements, the position of railway-sidings, and other considerations. The author is of opinion that it is desirable, not to say essential, that the greatest length of an oblong shaft should be across the cleat of the stone, so that the long side may be in the position most easily supported.

(*e*) When sinking through the leader of a trouble, running as shown in Figs. 1 and 2 (Plate I.), across the narrow width of the shaft, the danger to the men and the cost of securing the sides of the shaft is enormously increased in the case of the oblong shaft. It will be readily

recognized that the mass of stone shown in Fig. 1 at A, and weighing about 120 tons will be very liable to fall, especially if the weight of the leader about 250 tons, be added. Further, after the leader of the trouble is passed through, and has left the shaft, if the beds rise towards the leader, there will also be a quantity of stone under the leader very difficult to support; this is shown at B in Fig. 1.

(*f*) The timber-lining will not last so long as brickwork, and seeing that the shaft is the one entrance into the mine through which all the men must pass in going and coming from their work, it is desirable that it should be made as safe as possible by being securely lined throughout. Some of the rock met with near the surface may be left unlined, but after a few years such places require frequent attention.

In order to obtain the greatest advantage from the use of rock-drills in sinking or tunnelling, it is necessary that a given length be driven by each series of holes, and that all the holes of such a series should be fired simultaneously, either by electricity or by a quick-running fuze, but there is some danger in using the latter. Not only where rock-drills are used, but where the holes are drilled by hand, much better results are obtained in all cases by firing all the holes at once by electricity.

It is essential for speed in sinking to get one or more rock-drills into the bottom of the shaft as soon as a clear place can be made ready after blasting, and it is the especial duty of the chargeman to concentrate the labour on that part of the pit-bottom which can soonest be got ready for the machines. By this means three or four holes (sometimes more) can be drilled before the whole of the stones have been filled away. The whole of the drilling for the next length is then completed before the machines are taken out of the pit.

The number, position, and depth of the holes to be drilled in the bottom of the pit for each round naturally varies according to the nature of the rock being passed through.

In hard limestone or very hard sandstone, as the Pennant rock of South Wales, there should be about nine sumping-holes about 4½ feet deep and from twenty to twenty-two canch-holes round the sides, each about 4 feet deep (Figs. 3, 4, 5, and 6, Plate I.) In ordinary sandstone, probably nine sumping-holes 6 feet deep, and from eleven to thirteen canch-holes 5 feet deep, will be sufficient. In shale or mild sandstone, nine sumping-holes drilled to a depth of about 6½ feet, will clear out 6 feet of stone, leaving the sides perfectly perpendicular, or at most requiring two or three

additional short canch-holes, which are put in by hand during the time that the loose stones are being sent out of the pit.

Where both sumping and canch-holes are drilled, the sumping-holes are fired first, an iron rod, with a loop on the top, being put into each canch-hole to prevent them from being filled up by the loose stones from the shots. While the workmen are filling away the stones from the sumping-holes, the canch-holes are being charged, and are fired at the most suitable opportunity. Where no canch-holes are required, all the sumping-holes are fired together.

The work of drilling can be occasionally expedited by leaving some of the holes short, as bored by the rock-drills, and finishing them by hand-jumpers.

The depth sunk by each round of holes, according to the methods herein described, is:—

	Feet.		Hours.
Hard limestone	4½	in	18
Hard sandstone	5¼	„	18
Shale and sandstone	6½	„	16

The average quantity of gelignite used is as under:—

	Lbs.	
In hard stone, for a length of 4½ to 5 feet—		
Nine sumping-holes 3 lbs. each	27	
Twenty canch-holes, ¾ lb. each	15	
Total		42
In mild stone, for a length of 6 feet—		
Nine sumping-holes 3½ lbs. each	32	
Eight canch-holes ¾ lb. each	6	
Total		38

These quantities may seem excessive, the aim, however, is not only to lift the stone, but to break it up and make it easy for the workmen to fill without having to break it with hammers.

It may be suggested that the position of the canch-holes, as described, might be liable to damage the sides of the shaft, but this damage is not likely to occur in practice.

The weight of stone lifted with each round of shots averages:—

	Tons.
For hard stone	130
For mild stone	155

It is no uncommon experience for three men to drill six holes with two machine-drills during the time that twelve men are drilling four holes by hand: the special advantage in favour of the use of rock-drills in hard stone being that the same work is effected in about half the time.

The following average results per week have been obtained with the rates of wages now prevailing (May, 1894):—

	Depth Sunk.	Cost per yard.								
		Wages.			Explosives.			Total.		
	Feet.	£	s.	d.	£	s.	d.	£	s.	d.
Very hard limestone, without partings	30	10	4	9	1	18	0	12	2	9
Coal-measure shales and sandstones ...	39	7	12	6	0	19	0	8	11	6

The plant required for the work is as follows:—

An air-compressor having an air-cylinder, 16 inches in diameter by 24 inches stroke, with a 20 nominal horse-power boiler attached. Each drill when working will require about 30 lbs. of coal per hour, working at most four hours per day, and the consumption for four drills will be 480 lbs.

Where it is possible to obtain the steam for the air-compressor from the boilers supplying the winding-engine, the cost for steam is greatly reduced, and by placing the air-compressor near the top of the shaft, so that the assistant banksmen may attend to it, there is a further saving in the cost of labour.

Four rock-drills as under:—Two drills with cylinders, 3½ inches in diameter, capable of drilling a hole 7 to 8 feet deep, and finishing with a diameter of 2¼ inches at the bottom; two drills having cylinders 3 inches in diameter, capable of drilling a hole 6 feet deep and 1½ inches in diameter at the bottom.

Percussive rock-drills with a long stroke, having an automatic rotating arrangement and a screw worked by hand for turning them down as the hole progresses, are found most suitable for the work. Rotary drilling-engines, both with twist-steel drills and diamond drills, have been tried with only moderate success. The drilling-engine with the twist drills was perhaps the most suitable of the two, but owing to the frequency with which bands of ironstone and hard sandstone were met with, which the drills will not touch, their use was abandoned. Diamond boring-machines were found to be too slow.

The pipe required for conveying the compressed air down the shaft to drive four drills should be 2½ inches in internal diameter and of light wrought-iron, the drills being connected to the bottom of the pipe by flexible tubes ¾ or 1 inch in diameter and from 30 to 36 feet long, having an instantaneous coupling to attach them to the wrought-iron pipe.

A heavy circular iron frame with screws to set out against the side of the shaft to keep it steady—hanging on two ropes—worked by a crab-engine, having two drums capable of being worked together or separately, appears to be the best arrangement for carrying rock-drills

in a pit-bottom, but it is found very difficult to keep such an arrangement from rocking when all the drills are running. A frame of this description—by being somewhat less on the outside diameter than the diameter of the walling—could be readily used as a scaffold for walling or other purposes. There is, however, no difficulty in working the machine-drills on ordinary tripod-stands: in fact, taking into consideration the slips which are met with in the stone, probably the holes can be put in to a greater advantage when using tripod-stands than by any other means. In an oblong shaft the rock-drills are put on stretcher-bars, and all the drilling is completed before they are taken out, except the holes in the corners, which are generally drilled by hand. The holes are then fired in four series, the first fired being five or six holes out of the middle of the pit.

There are many kinds of steel bits used for rock-drills, but some of the best are shown in Figs. 7, 8, 9, and 10 (Plate I.). In all cases it is desirable to use as simple a bit as possible so as to save blacksmith's work.

For hard stone, + or X bits (Figs. 7 and 8) are most suitable. For sandstone, bits with a broad edge, not sharpened (Fig. 9), and for soft ground, bits as shown in Fig. 10 are most suitable.

The + bit is more easily sharpened than the X bit, but will not bore in places where the work can be done by the latter, whereas the X bit will bore under all circumstances where work can be done by the + bit. The bit shown in Fig. 10 bores more rapidly: having a piece cut out of the sides, it keeps the hole round, and prevents canches from being formed. It is the best all-round drill, except for very hard stone.

There are two modes of firing by electricity, *i.e.*, by high-tension or low-tension fuzes. Low-tension fuzes are perhaps more liable to go wrong, or to fail in manufacturing, owing to the extreme fineness of the platinum wire used. Notwithstanding this defect they seem preferable for use, particularly in mining work, where it is essential that there shall be no missed shots. Each fuze can be tested before being sent down the pit, and when all the holes are charged and the connexions made, the whole blast can be re-tested before firing, care being taken to have the men out of danger before the test is applied, lest any fuze more sensitive than its fellows should explode during the test. It is essential that the cables should be tested as soon as the shots have been fired, so that they can be repaired if necessary before being again required; that each piece of connecting

wire, old and new, should be tested before putting them ready to send down the pit, and that each fuze should be tested although the latter are tested and guaranteed before being sent from the manufactory, and again that the blast should be tested after all connexions are made. The cables used are good copper wire, No. 7 wire-gauge, well insulated and braided, and in no case should both wires be in one cable, but they should be entirely separate, and placed 2 or 3 feet apart in the pit. The author's experience with two wires in one cable has been most unsatisfactory. It is also essential that the cables should be kept as dry as possible.

The copper wire used for connecting the shots in the pit-bottom is No. 14 wire-gauge, insulated with a thin covering of guttapercha at a cost of about 60s. per mile, and most of the wire can be used several times over.

The fuzes, cables, etc., are tested by passing a slight current of electricity through them attached to a galvanometer: the needle should move to one place on the dial if the fuzes are right.

The advantages claimed for the electrical system of shot-firing are:— (*a*) The greater despatch and cheapness with which work can be done. (*b*) The greater safety of the men, there being less chance of missed-shots, and no chance of a shot hanging fire. (*c*) The absence of smoke after the shots are fired.

Black powder is the cheapest explosive for use in dry work, but taking into consideration the extra labour entailed in making ready the holes, a high and powerful explosive is usually found more economical, the charge does not occupy so great a length of the hole, the full force is exerted at the bottom of the hole, with less risk of leaving sockets, as in the case of black powder; this is important, as it is desirable to have the pit-bottom as level as possible for the machines.

The two methods of shutting-off water in shafts most generally used are by cast-iron tubbing and walling built of brick and cement. The following costs have recently been given of the respective modes, which appear to have been allowed to go uncontradicted:—

	Per Foot. £
Tubbing...	26
Brickwork	18
Cement	8

Very much depends, of course, upon what items are included in the cost, and the pressure of water, but taking it in all cases that the cost of sinking is the same it may be supposed that it is not included in the prices given.

In several long lengths of water-tight walling, extending for something over 240 feet, the cost of the walling, where it was thickest, that is at the bottom, was £6 6s. 8d. per vertical foot, including the cost of labour and material and the extra cost over and above the price of sinking for making the shaft sufficiently large to admit of the extra thickness of walling (probably 3½ feet larger in diameter than is necessary for tubbing). This price seems to compare very favourably with the prices above named. The cost price for tubbing this length would have been about £12 per foot.

The walling was put in as shown in Figs. 11 and 12 (Plate I.), that is, the walling was built about 3 feet at a time of 4½ inches brick-work, in front of which were placed sheet-iron plates 14 to 16 wire gauge. In front of this there was brickwork about 20 inches thick, leaving a space of 1½ inches between the inner and outer walls to be filled in with cement, in which the iron plates were embedded. As the pressure of water became less, the thickness of the front wall was gradually decreased from 20 to 15 inches and from 15 to 10 inches, the space for cement being kept in one continuous length. The best results were obtained when the water in the pit was allowed to follow the work, so that the cement set under water, but this is not in all cases possible.

The walling consisted of a good class of shale-brick of the ordinary building size, set in cement. It is preferable to put a short length of solid work in at the bottom under the water-bearing strata where possible, and to convey the water through it in pipes, as shown in Fig. 11. It is generally found, when the water is plugged off, that a considerable quantity percolates through the bricks for a few days, but as a rule it gradually takes off and the walling then becomes quite dry.

Attempts have been made to carry on the sinking and walling of shafts at the same time by use of the Galloway stage, but the result was not all that could be desired. As the stage gradually goes up and the sinking goes down, the stage gets a long way out of the bottom of the shaft, necessitating the loss of considerable time and the use of great care in steadying the tub. Where a stage is used and kept near the bottom, with the tub running in guides, the work can be most quickly got out, as the tub requires very little steadying, and it is a great convenience having the stage available, so placed that men can go to any part of the shaft at a moment's notice. It also affords some protection to the men in case of anything falling into the pit.

The pneumatic water-tub is an arrangement intended to replace the bowling of water and to enable sinking to be carried on under circumstances which would otherwise necessitate the use of pumps.

The original idea was to obtain a vacuum by filling the water-tub with steam in the pit-bottom and allowing it to condense. This was found to be too slow, and was improved upon by means of an air-pump on the surface pumping out of an old boiler; pipes were taken from the vacuum chamber to the bottom of the shaft, and attached to the water-barrel by means of a flexible tube having an instantaneous coupling.

As soon as the tub arrives in the bottom of the shaft the connexion is made, and a valve on the end of the flexible tube opened; the air is then exhausted from the water-tub, and the water rises through the bottom valve, filling a 600 gallons tub in about thirty seconds. 100 gallons of water per minute can be lifted by this means with a fair amount of satisfaction, but as soon as that quantity is exceeded, it is advisable to have pumps, notwithstanding the temptation there is to continue with a tub as long as possible.

The best results in sinking are obtained with the old lift-sinking set of pumps—hanging on ground-spears—worked by an engine on the surface: this allows the sinking to be carried on without interruption of work, caused by the pumps being damaged by shots.

Damage to the bottom-pieces of pumps—that is the snore-piece of a lift-sinking set, which frequently occurs from the shock, where high explosives are used—is always a source of trouble and delay; but it can be avoided by keeping the pumps 3 or 4 inches off the bottom when the shots are fired. Where the pumps and pumping-engine are suspended in the shaft, as in the case of the Worthington pump, and pumps of that type, it is advantageous to have all the connexions of the steam, exhaust, suction, and rising-main pipes, where they join the engine, made with a short length of flexible tubing.

The Chairman said that this paper was a very useful and practical one. The members who attended the recent Whitehaven meeting would notice that most of the shafts in that district were of oblong shape. In bad ground it was almost impossible to make the shafts rectangular; and for this reason, no doubt, the round shaft would be most generally preferred. Mr. Coulson said that—

In order to obtain the greatest advantage from the use of rock-drills in sinking or tunnelling, it is necessary that a given length be driven by each series of holes, and that all the holes of such a series should be fired simultaneously, either by electricity or by a quick-running fuze, but there is some danger in using the latter. Not only where rock-drills are used, but where the holes are drilled by hand, much better results are obtained in all cases by firing all the holes at once by electricity.

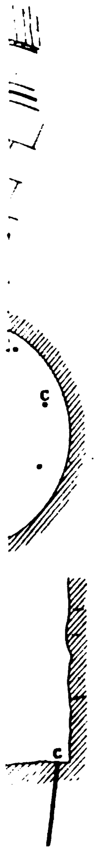
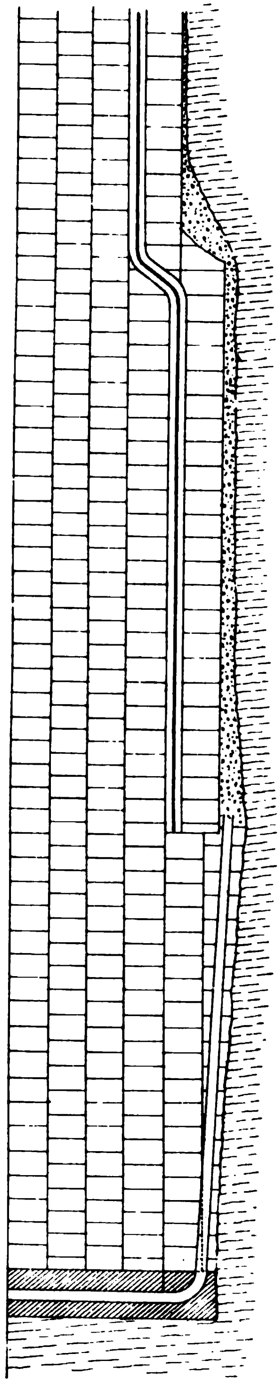
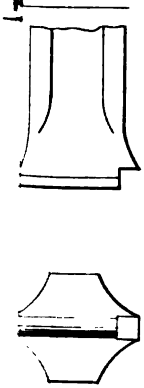


FIG. 11.



Scale. 2 Feet to 1 Inch.

FIG. 10.



He agreed that it was desirable to lift the stone by simultaneous shots if possible. He had tried to utilize this method in the Cleveland ironstone-mines; but the trials were not successful, as the ironstone required a slow explosive. He would like to ask Mr. Coulson if he had ever found a dangerous atmosphere after shot-firing in a shaft? He agreed with Mr. Coulson that in hard stone the percussive rock-drill was the best, but he was still hoping to find some means of getting over the difficulty of using a rotary drill in hard stone. He (the Chairman) thought it was not possible to drill a deep hole with percussive drills without water; and they would be glad to know whether water was used by Mr. Coulson, or whether he worked dry?

Mr. W. C. Blackett asked Mr. Coulson if he had experienced any difficulty in winter in shafts tubbed with brick by the frost frittering away the sides of the shaft?

Mr. Thomas Douglas asked whether Mr. Coulson's experience in the matter of firing shots simultaneously enabled him to say whether he had attained that object? He concluded that there had been no difficulty from the fumes or smoke arising from the firing of the shots, although he would have thought it probable?

Mr. F. Coulson said he had never had any trouble with fumes except in the case of one or two experimental trials of different explosives, whose ignitions had not been complete. In one case, 34 holes had been fired at once; and the men went back within one minute after the shots had been fired, and there were no fumes whatever. Water was used in drilling the holes, but in a dry pit the small quantity used could be sent down in pails, no regular supply of water being necessary. He had not found any case of bricks frittering away as suggested by Mr. Blackett, although he had found broken bricks. He had never known any walling to give way from this cause, except in old shafts where it had occurred, to a certain extent. He had put in five lengths of water-tight cement walling varying from 180 to 250 feet in length.

The Chairman proposed a vote of thanks to the writer of the paper.

Mr. W. O. Wood, in seconding the resolution, said that the paper was valuable, bearing, as it did, upon a subject which seldom came within the scope and experience of mining engineers in this district, where all the pits required were sunk.

Mr. R. W. Moore read the following paper on "Improvements in Brick-kilns":—

IMPROVEMENTS IN BRICK-KILNS.

BY R. W. MOORE.

In an ordinary brick-kiln, the products of the combustion of the coal used in the process of burning are allowed, after circulating amongst the charge, to escape direct to the chimney without further utilization, and as the combustion is imperfect, resembling more or less destructive distillation, a large proportion of the volatile products passes unconsumed up the chimney, and is consequently wasted.

Another disadvantage of using the old type of kiln is that excessive firing, entailing an unnecessarily large consumption of fuel and a considerable waste of time, is absolutely requisite to ensure that the whole of the contents are burnt; and thus the front part of the charge, that nearest the fire, is discoloured, whilst the material at the back is frequently underburnt. A further disadvantage that the old kiln possesses is the difficulty of ascertaining when the moisture is driven off the stack of raw material and when the full heat may be applied.

These disadvantages have been got rid of by the improvements which form the subject of letters patent (No. 3,343, 1890), which have been applied with marked advantage by the Seaton Firebrick Company to their kilns at Moorhouse Guards.

These improvements in the construction of brick kilns consist in conveying what was hitherto waste gas (the result of the imperfect combustion of the coal consumed in the space left between the charge and the front of the kiln), after it passes through the interstices of the charge, into a combustion-chamber, shaped like a beehive, built at the back of the kiln, by means of three flues, as shown in Figs. 1, 2, and 3 (Plate II.). Fig. 4 shows the application of the improved system to an old kiln.

Two plugs or valves admit a small proportion of air into the top and bottom of the combustion-chamber, thereby raising the ignited gaseous mixture to a white heat, and bringing the brickwork intervening between the combustion-chamber and the kiln into an incandescent state. This intense heat at the rear of the kiln ensures that the charge is burnt as well at the back as at the front, and experience has shown that the charge is evenly burnt throughout. From the bottom of the combustion-chamber the ignited gas is conducted by a flue passing immediately beneath the

kiln, thus heating it still further along its entire length, into a main flue that traverses the full length of the range of kilns, whence it can be gradually admitted by regulating-dampers into one or more of the adjoining kilns by branch flues that enter the front of the kilns, as shown in the drawings.

In describing the *modus operandi* of the new kilns, it is first of all necessary to explain that the entrance to the kiln is walled up after the coal has been kindled under each fire-hole. The admission of air is regulated by dampers at the fire-holes, and all the orifices on the front and the crown of the kiln are sealed up so as to exclude the admission of air. The practice is to admit the ignited gas by degrees into the newly-charged kiln or kilns adjoining that in operation, and to turn the full heat on only when the moisture has been expelled from the raw material to be burnt in the other kiln or kilns.

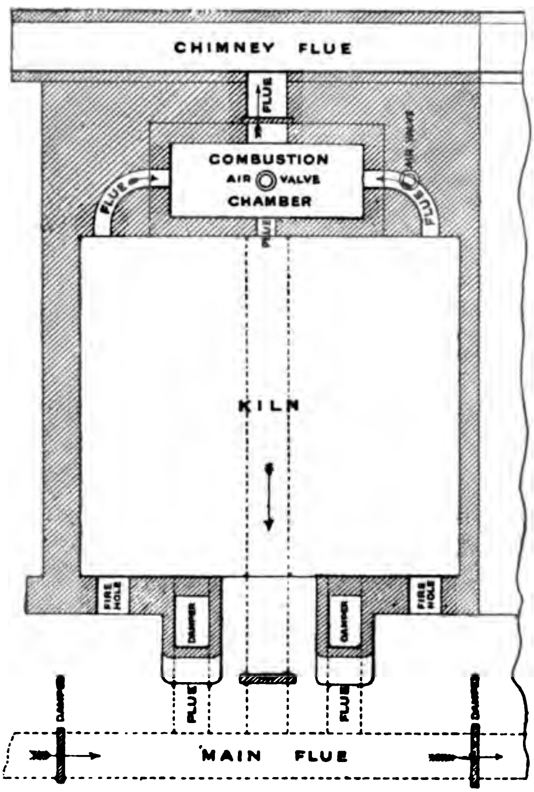


Fig. 4.

If none of the gaseous mixture is wanted at another kiln, the damper in the flue leading from the combustion-chamber into the chimney-flue is kept open and the damper for the underneath flue is closed. But when the ignited gas is required for another kiln, the damper in the connexion between the combustion-chamber and the chimney-flue is closed to an extent sufficient for sending round such a quantity as will dry the moist contents of that kiln; and the damper in the underneath flue is opened as well as the divisional damper in the main flue, and the dampers in the branch flues leading into the front of the kiln. After the moisture has,

in this way, been entirely driven off, the damper in the passage leading from the combustion-chamber to the chimney-flue is shut down altogether, and the whole of the heated vapour is passed through the contents of the second kiln and the combustion-chamber attached thereto into the chimney-flue; or, if it be desired to dry the contents of a third kiln, it is only necessary to close, or partly close, the damper in the flue connecting the combustion-chamber of the second kiln with the chimney-flue, and open the damper in the underneath flue, when the current will pass by the latter under the second kiln into the main flue, and thence by the branch flues into the front of the third kiln in the same manner as before described.

It has been found by experience that 6 tons of coal will, by the improved process, burn the contents of one kiln completely, and dry and heat to redness the contents of another; and that it is necessary to use 6 tons more of coal in the second kiln, in order to burn the charge in that kiln thoroughly. However, by the time that the charge of the coal in the second kiln is wanted the first kiln is done with; and the products of the combustion of the coal in the second kiln can be utilized exactly in the same manner as has been before described. And so the process goes on with the remainder of the kilns constituting the range.

Under the old system, each kiln at Moorhouse Guards colliery and brick-works held 8,000 best firebricks, which occupied 60 hours in burning, and cost £1 for labour during that operation. The consumption of coal amounted to 16 tons, costing £4. The total cost of burning the kiln was therefore £5, or 12s. 6d. per thousand.

Each of the patent kilns holds 10,000 best firebricks, occupies only 30 hours in burning, and costs only 10s. for labour. The coal consumed amounts to 6 tons, of the value of £1 10s. The total cost of burning firebricks by the improved system is therefore only £2 a kiln, or 4s. a thousand. The saving effected by the new kilns in the cost of burning is therefore about 8s. 6d. a thousand.

One of the new kilns can be used forty times a year, producing an output of 400,000 best firebricks, and effecting a saving of £170 during that period. It can be built for the sum of £100, exclusive of the royalty payable on the patent—little more than one of the old pattern kilns would cost. The improvements can be applied to existing kilns of the old type at a merely nominal cost.

The improved process of burning has been applied with equal success to the manufacture of common bricks by the Seaton Firebrick Company, and at a much reduced cost. By the old method, the burning of common

bricks cost 5s. 6d., whereas they can be produced with the improved kiln at a cost of, at most, 1s. 6d. a thousand.

Ten of these improved kilns have been in use at Moorhouse Guards for the last three years, and in addition to turning out the best class of firebricks, they have produced large quantities of fireclay-blocks for the lining of blast-furnaces, cupolas, tuyeres, stoves, etc., where intense heat has to be withstood, at various iron and steel-works in the district.

The following is a copy of an analysis made recently by Mr. W. Bedford, then of the Whitehaven Hæmatite Iron & Steel Co., Ltd., Cleator Moor, of a brick burnt in one of the improved kilns at Moorhouse Guards, showing clearly the refractory power of the firebrick :—

Gas in ignition, bituminous matter, and moisture	0·210	per cent.
Silica	72·500	„
Alumina	27·000	„
Iron oxide	0·071	„
Magnesia	Trace	„
Potash and soda	0·127	„
Total	100·008	

The Chairman said that the paper described a very useful and interesting improved kiln. He agreed with the author that in an ordinary brick-kiln the products of the combustion of the coal used in the process of burning were allowed, after circulating through the charge of bricks, to escape direct to the chimney ; but in many instances, the waste heat was utilized under the drying-floor. At the present time brick-kilns were being fired by the waste heat from coke-ovens.

Mr. W. O. Wood said that the old kiln, of course, was not by any means perfect, but by long experience the fuel required had been reduced to a low figure, and the amount of waste was less than that referred to by Mr. Moore. The bricks at the back end of the kilns, ordinarily used in the county of Durham, are always as well burnt as those at the front end of the kiln, if the bricks have been properly set. The consumption of fuel mentioned in Mr. Moore's paper appeared very excessive. Under the old system, he stated that 40 cwts. of coal were used per thousand bricks. The old-fashioned kilns containing 8 to 8½ thousand bricks only consume 21 cwts. per thousand in this district. Mr. Moore states that the improved kilns use 12 cwts. of coal per thousand bricks. By adopting hot-air furnaces at the Cornsay brick-works, the consumption of coal has been reduced to 12·8 cwts. per thousand bricks, or about the

same quantity as is required by the improved kiln. The system of hot-air furnaces is being applied to round kilns, and it is expected that the fuel will be reduced to about 10 cwts. per thousand bricks.

Mr. T. DOUGLAS said that the consumption of coal would of course depend to some extent on the character of the coal used. He thought that the consumption of the present kilns was too large, and much more than should have been used; 2 tons per thousand bricks appeared to him to be an excessive quantity, and very much in excess of what was being used even now in ordinary kilns. Even the smaller quantity which was being used in the improved kilns would, he thought, be found to be in excess of the quantity consumed in the ordinary kilns of the Durham district.

Mr. W. C. BLACKETT said that he agreed with the remarks of Mr. Douglas and Mr. Wood. The kilns as they were burnt in this part of the country were not consuming anything like the quantity of coal mentioned in the paper as being used in the old kilns before the improvements were introduced.

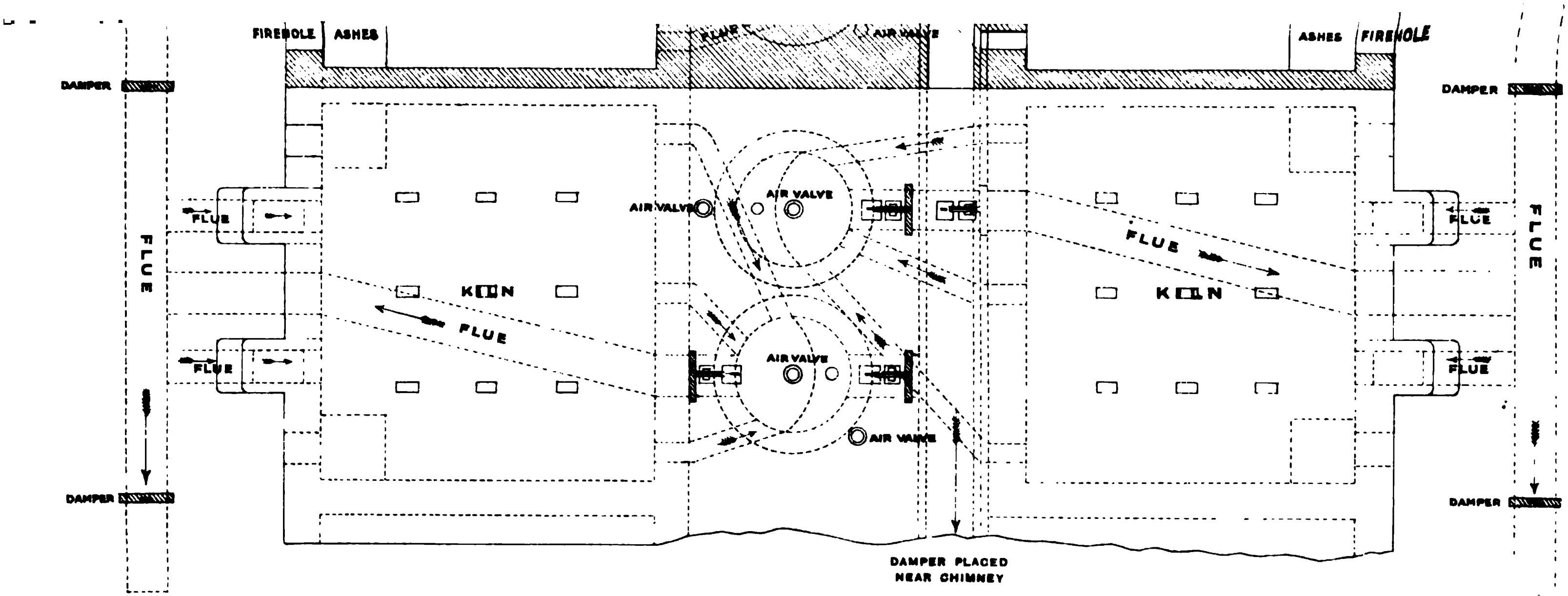
Mr. MOORE explained that the coal used for the burning of the kilns was small and duff of the very poorest quality, of which a larger quantity was necessarily consumed, and certainly not of the value which was put down in the paper of 5s. per ton. He had really put the price higher than it should be. He would like to know exactly the quantities and qualities of coal used at kilns in this district, so as to compare with those used in Cumberland.

The CHAIRMAN moved a cordial vote of thanks to the writer of the paper.

Mr. W. C. BLACKETT seconded the resolution, which was agreed to.

The following paper by Mr. J. M. MAIN on "The Working of Hæmatite in the Whitehaven District" was then read:—

To illustrate Mr R. W. Moore's Paper on "Improvements in Brick-kilns."



Andrew Reid & Co. Ltd Newcastle on Tyne.

THE WORKING OF HÆMATITE IN THE WHITEHAVEN DISTRICT.

BY J. M. MAIN.

The working of the ores in the Carboniferous Limestone area of the Whitehaven district has hitherto not received much attention. The only description of which the writer is aware is a paper by Mr. J. D. Kendall, published in *The Transactions* of the North of England Institute of Mining and Mechanical Engineers,* and the same author's necessarily brief outline in his *Iron Ores of Great Britain*.† It is proposed to give, first, a general description of the working of the different kinds of deposits, and then to describe particular instances where special or marked characteristics have been observed, adverting also to some of the more important mining requisites that are in general use in the district.

Three distinct forms of hæmatite occur, viz.:—Vein-like, bed-like, and irregular or patchy masses, the latter locally termed "pockets," "sops," and "guts," the gut-like deposits continuing longitudinally for considerable distances, and often running parallel to the faults which are found near them, or with which they may be associated.

VEIN-LIKE ORE.

Vein-like ore occurs along the line of faults, of which there are a number in the district, and these are of primary or secondary importance according to their throw. It may be noted that the majority of the faults run in a north-westerly and south-easterly direction, and have an average bearing of about 45 degs. west of the true meridian. There are, however, instances of important faults (termed east-and-west faults) running almost at right angles to the other series (termed in contradistinction, north-and-south faults).

Vein-like ore occurs between two walls, locally termed the foot or lying wall, and the hanging wall, and in sinking a pit to work this class of ore, it is a point of good mining, and one which should never be neglected where practicable, to fix the site of the shaft on the upthrow side of the fault, and, if possible, clear of the outcrop of the vein at the surface, the object being to prevent damage to the shaft from drag, which

* Vol. xxviii., page 109. † Page 54.

in the case of a vein-like deposit of any magnitude is almost certain to occur. If the hade of the fault be low, this will necessitate longer drifts in the lower levels, and consequently make the first cost of developing the mine greater than would have been the case had the pit been sunk in the hanging wall directly on to the deposit, but this increased expenditure is much more than counterbalanced by the advantages gained (in subsequent working) from having the shaft in firm and solid ground.

If there are any insuperable difficulties in the way of sinking the shaft on the upthrow side, owing to the position of the fault in the royalty, then it should be sunk at a sufficient distance from the fault on the downthrow side to escape as far as possible from the effects of surface-drag.

There are no deposits of this kind in the district that can properly be designated true veins, nor are they always entirely vein-like, as in many cases a combination of vein-like and bed-like ore is found. This remark, of course, only applies to the geological area under consideration.

The usual method of working vein-like ore may be briefly described. Having sunk the shaft as above indicated, levels are driven off at right angles to the fault at distances of from 120 to 180 feet apart vertically, the number of levels depending on the extension of the vein in that direction. After the ore has been intersected and its width proved, longitudinal workings are commenced right and left, rises are put up on the footwall as the various workings advance, the pillars between each rise being from 60 to 70 feet in length. Intermediate horizontal workings are then driven from the rises, middlings of from 15 to 30 feet being usually left between, and thus the system of splitting up the vein goes on. The rises form hoppers, shoots, or (as locally termed) "hurries" for conveying the ore from the intermediate workings to the different levels communicating with the shaft.

Until communication by means of the rises has been effected with the different levels, the ventilation of the workings is obtained in the usual way, viz., by bratticing of brick or canvas, or by wooden boxes.

In the case of a wide vein, say from 100 to 120 feet, two longitudinal workings may be driven right and left from the shaft-drift, care being taken in so doing to "blind" the opposite workings, not only to strengthen the drift, but as a safeguard in carrying on blasting operations. Unless the hanging and footwalls are of a strong character, it is advisable not to drive the workings close to them, but to leave a portion of ore against them for support. The size of the workings varies from 8 to 20 feet wide and from 8 to 12 feet high. These dimensions are, however,

altogether regulated by the nature of the ore: where that is very hard and free from joints or cleats, larger workings than those stated may be safely carried on, and in such cases little or no timbering may be necessary. This, however, is the exception, not the rule, as in most deposits the character of the ore is subject to frequent changes, and renders timbering necessary to a greater or less extent, even in the first series of workings.

It may here be advisable to describe the method ordinarily adopted in timbering the ore-workings and driftways in such a deposit, and this description will suffice for the workings in the other forms of deposits hereafter to be described.

Sets consisting of two legs or uprights and a headtree are put in from 3 to 4 feet apart, the size of the timber used depending on the width of the working, the character of the ore, and the condition of the roof. When there is likely to be a considerable side pressure, the tops of the legs and the ends of the headtrees are half-checked or (as locally termed) joggled, to prevent the legs from being pushed from the perpendicular position, while the foot or bottom of the legs (usually the thickest part of the timber) is sunk, or, as it is termed in miners' phraseology, "has a footing made" some inches into the sole of the working, and if the latter is of a soft nature, pieces of flat timber are in addition placed immediately under the foot of the legs to prevent, as far as possible, their being forced downwards by top weight.

The joggling process is more especially necessary, if the working has for one of its sides the foot or hanging wall, the former consisting frequently of shale or slate-rock, and therefore liable to be affected by the air and dampness of the mine. Should most danger be apprehended from top or roof pressure, the upper ends of the legs are slightly hollowed out with an axe to receive the headtree, and thus obtain as good a bearing surface as possible. In weak or loose ground, coverwood (boards of from 5 to 12 inches wide, and from 1 to 2 inches in thickness) and sometimes also poling (the thin or top ends of the round timber) is placed over the top of the headtrees, and when the latter is used it is sometimes crossed by coverwood.

In drifting through fallen or broken ground, great care is necessary in fixing the timber, and the most experienced men are employed to perform this work.

After the deposit has been opened up in the manner described, and the workings in the upper levels have been carried to the extreme limits of the royalty, the work of taking out the middlings farthest from the shaft is

commenced, the ore in these being stoped in benches either from the top downwards or from the bottom upwards, as may be considered advisable. Some artificial blocking of the space between the two walls of the vein is often necessary before the ore can be taken out for any great distance. When the space between the walls is not too wide, a number of strong stemples may be firmly secured between and at right angles to the walls, and covered with 3 inches planks. All the *débris* and stone which may be got in carrying on the workings are piled on the top, and form in time an artificial middling, which may be further strengthened by putting in a few stretcher-props here and there. When it is difficult to obtain *débris* for packing, timber is used more largely.

If a wide deposit has to be dealt with, then stumps or parts of the middlings are left for the support of the walls. In such cases it often happens that a collapse of the walls occurs sooner or later, and any ore which may be buried in the fall can only be recovered by drifting through the fallen ground. These are termed robbery workings.

It is not always, however, in these deposits that workings can be carried on with rigid regularity for any length of time, as nips and enlargements of the ore-body occur frequently; while in some cases it may cut out completely and continue so for a considerable distance, or again it may become very much mixed with stone and other impurities.

The system of working the ore therefore cannot possibly be uniform, but must be designed to suit the special nature of the varying conditions. Where horses or large blocks of stone occur, these are, as far as possible, left undisturbed, and serve as supports to the walls of the vein.

The flats which frequently extend from these vein-like deposits are worked in a similar manner to the bed-like deposits noticed hereafter.

One of the largest and most productive of these vein-like deposits is that found on the north-west and south-east fault running through the Windergill, Postlethwaites Eskett, and Salter Hall royalties. The bearing of the fault on which this ore lies is about 34 degs. west of the true meridian. The longitudinal extension of the deposit through these three properties is about 3,000 feet, while it has been proved and worked to a depth of about 270 feet. It presents the usual characteristics of such deposits, viz., nips, enlargements, and flats. The latter occur in the third and fourth limestones.

Fig 1 (Plate III.), is a plan of some of the first workings of a vein-like deposit, the irregular direction of some of the longitudinal workings being caused by the nips and enlargements of the vein, while a long stretch of barren ground is seen in the lower levels. Fig. 2 (Plate III.),

is a section along the line A B (Fig. 1), and shows the relative vertical position of the various levels and workings as well as some of the characteristics of the ore-deposit.

Bed-like Deposits.

There are seven distinct beds of limestone, known as the first limestone, second limestone, and so on, which, together with the sandstones and shales separating them, form the Carboniferous Limestone series of the district. In each of these beds of limestone, hæmatite is found to a greater or less extent. The bed-like deposits are so called because they follow the dip or trend of the limestone-beds in which they occur, and frequently occupy a position either in the roof or sole of such beds, but sometimes they extend from roof to sole. They most frequently occur in the first, second, third, and seventh limestones.

The usual method of working this class of deposit is by the pillar-and-stall system. The pit is sunk in a convenient position in the royalty, and as far as possible to the dip. When the ore-bed has been reached, and adequate provision has been made either by sump or lodge for contending with the water, a level is driven at right angles to the dip of the strata, while, at the same time, a heading is carried on to the rise. As the branch workings on the levels advance, stalls, bords, throughs or (as locally termed) thirls, are commenced—leaving pillars 24 to 45 feet in length. From the heading also other workings are branched off, with from 18 to 36 feet of solid ground between each. The pillars thus formed (when the thirls from the various level workings are holed) measure from 430 to 1,620 square feet. Smaller pillars will suffice in the case of very hard and strong ore.

The width and height of the workings depend very much on the hardness and thickness of the ore and the nature of the roof. In the case of very hard ore with a good strong roof, and where the thickness of the bed will permit, the workings may safely and with advantage be made from 15 to 20 feet square, but when the ore is tender they are usually driven from 9 to 12 feet square, while timbering in the latter case is necessary, more especially if a shale-bed (as very often happens) overlies the deposit. No definite dimensions however can be fixed for regulating the size of the workings in these deposits as can be done, for instance, in the working of the thicker coal-seams, as the varying conditions met with render it impracticable.

The engineers or managers of these mines require therefore to exercise their discrimination and bring practical experience to their aid in coming

to a decision on this point, although the writer thinks that in many instances errors of judgment have sometimes been committed (especially in the earlier working of these deposits) in making the first workings both too high and too wide, and thus not only incurring considerable risk to life, but likewise causing great loss of mineral to the proprietors of the mines.

A working in one of the first pits that the writer descended in this district, about twenty-four years ago, was an instance of this error. The deposit was bed-like, and this particular working occupied the full thickness of the limestone-bed, extending from sole to roof, and measuring on an average 40 feet high. The whole of this height was taken in one working, with the exception of a hard band of ore in the roof, from 3 to 4 feet thick. This ore-band was left to support a black shale-bed above it, about 3 feet in thickness. The working at its greatest width measured about 100 feet, while it had a longitudinal extension at that time of nearly 200 feet. As all the ore had to be taken from the face to the shaft throughout the full length of this immense cavity, while at the same time a brake-road was in constant operation in the very centre of it, and as no reliable means could be adopted for testing the soundness of the roof, a covered way had to be made along the sole of the working at considerable expense, and involving great loss of time. Frequent falls from the roof occurred afterwards, although, fortunately, no serious injury to the miners resulted. This ore could have been worked in a much safer manner, and to greater advantage, had the first workings been of smaller dimensions.

The main heading is frequently used as the trail-road for bringing the ore from the various workings to the shaft, and so long as the gradient is light, "skutches" or sprags are used in running the loaded bogies or tubs down to the level drift. It frequently happens, however, that the beds rise at so steep an angle as to necessitate the making of an incline, worked either by a wire rope or chain and pulley, or by a drum furnished with an efficient brake. As the gradients of the beds are variable, sometimes running nearly flat, and at other times at a steep angle, a series of inclines are frequently in use in working a deposit. The full bogies (one or two at a time) bring up the empty ones, and swinging-platforms are used where the different workings connect with the inclines.

After the level workings have reached the extreme limit of the ore, either by being cut off by a fault or stone trouble, or by the boundary-line, the work of taking out the pillars is begun. When the roof is of a strong character, the pillar-ore can be obtained at considerably less cost

than when driving the thirls or stalls, the chief care necessary being to protect the line of workings either by pillars built of the stone that may be got in working the ore, or by pillars of wood or strong props. When wood is employed for this purpose, old railway-sleepers and squared Norway timber are very often used. Very little ore is lost under such circumstances, probably not more than 2 per cent., and where the ore is thin, the loss does not reach 1 per cent. More care is necessary and greater expense is incurred when the roof consists of a softer or less sound limestone or shale-bed, as a much larger quantity of timber is required, and in spite of all possible care being exercised, the superincumbent weight may cause a collapse of the roof. In such cases some of the pillars may have to be approached through fallen ground. Then slice after slice is taken off until the ore is removed. In this way the working back of the pillars is carried on, until that supporting the main heading is reached, which in the meantime is left undisturbed. The heading-pillars are then worked back from the inside in a similar manner until the deposit is exhausted.

Should the ore extend farther to the dip the shaft is deepened, and drifts or "eyes" are driven out at lower levels. The mode of procedure in working out pillar-ore is to commence at the rise side of the pillar, taking about 6 or 8 feet of the ore as a working-face, and carrying it down to the dip side of the pillar. When this has been done, and the roof behind secured as indicated, another strip of ore is in like manner taken out. Sometimes stumps of ore are left at the two corners of the pillars as a means of strengthening the roof, until the building of the stone or wood pillars is completed. These stumps can then usually be taken out with safety. Timber is set round the pillar in some cases, to keep up the roof whilst the pillar is being removed.

Where the ore-bed has been of great thickness and two tiers of workings are rendered necessary, the pillars of the top tiers may sometimes have to be left as near as possible over the bottom pillars with substantial middlings between the workings and strong arches of ore in the roof of the higher workings. The upper pillars are then first worked out, down to the sole of the top tier of workings. If the roof and ore are strong and hard, the working of the ore takes place from the inside outwards, but if the reverse conditions are present, then the working proceeds from the outside inwards, while the roof will require timbering. In the latter case, before proceeding with the work it may be necessary to support the roof of the lower workings, or fill them with *débris* (as afterwards described) if this has not already been done. When the top pillars have been brought back so far, as much of the roof-ore should be taken as can be

got out with safety; round larch timber is then placed across the top of the middlings with the ends resting on the top of the bottom pillars, and these are overlaid with coverwood and *débris* above the coverwood to a depth of 3 or 4 feet. The middlings may then be worked out from the bottom upwards, and the working of the bottom pillars afterwards commenced.

Should a general collapse of the workings take place before all the ore has been extracted, drifts are driven through the fallen ground from the nearest available points, and the ore worked out, as has already been described in speaking of robbery workings in vein-like deposits.

In certain conditions of the roof and ore, it is often considered advisable before commencing to remove the pillars, to pack with *débris* the waste area around them, close up to the bottom of the middlings—access drifts to the bottom of the pillars, and rises to the middlings being left through the *débris*. In this way, the ore in the lower tier of workings may be extracted with comparative safety, even should there be a collapse of the roof in the upper tier.

In some mines, instead of taking all the *débris* obtained from the various workings and development-drifts in the mine and depositing it on the spoil-bank at the surface, a large portion is used for the above purpose.

The bed-like deposits are subject to the same irregularities as those that occur in the vein-like deposits, viz., nips, vertical enlargements, and horses or large blocks of stone intermixed with the ore. These disturbances, of course, increase the cost of working the ore and render the above method of working liable to considerable alterations. The stone blocks are left as pillars, and they frequently deflect the workings from their intended course.

A good example of a bed-like deposit is that in Postlethwaites Fletcher pit near Moor Row. The ore is of a hard nature, but very rich in metallic iron, and has the advantage of a strong limestone-roof. In consequence of this, there is a very small percentage of loss in working out the pillars. The uniform extension of the deposit over a large area is also very marked. This deposit occurs in the second limestone.

Fig. 3 (Plate III.) shows the first workings in a bed-like deposit, and the pillars of ore left, as well as the stone disturbances that were met with. The ore averages 10 feet in height, and therefore was taken at the first working over the whole area. Fig. 4 (Plate III.) is a section of the same along the line A B (Fig. 3).

Irregular Deposits.

The third form of ore-deposit is that of irregular and patchy masses in the limestone. These deposits also occur in the vicinity of faults. They may be, and sometimes are, connected with vein-like and bed-like deposits.

This kind of deposit cannot be worked in any very systematic manner. The method usually adopted is as follows: assuming that the pit has been sunk and a level driven out to the ore, care must be taken not to drive the workings too large until the nature of the deposit is thoroughly understood. About 9 feet square is an average-sized working, but this of course is altogether dependent on the character of the ore. The first workings are driven in the same way as in the bed-like deposits, viz., by a series of working-places and pillars, until the enclosing stone is reached on all sides, and the horizontal extension of the ore at that level is known. If ore has been left in the roof, it is followed upwards either at the junction of the ore with the stone, or by plumb-rises in the ore at the most suitable points, with the view of ascertaining the vertical extension in that direction; and if the height of the ore will permit, another tier of workings is driven horizontally, leaving a middling of sufficient thickness between the sole of the upper and the roof of the first working. If the full height of the pocket of ore has been reached by the higher tier of workings, any leads of ore into the surrounding stone are now followed up, and, if the royalty is a rich one, other pockets of ore may be opened out in this way.

It may be that the connecting ore-lead is very small, and not workable to profit; but in this kind of deposit better results are obtained by following these than by drifting through the solid stone, unless ore has been proved by boring to lie at a convenient level, and at a short distance from some part of the working. In such a case, should there be no direct lead of ore, a stone-drift is at once driven in the direction of the borehole: advantage being taken of the existence of any shale-beds running in this direction, even although it may be necessary to go a little out of the direct course in doing so, the difference in cost in driving through limestone and shale being of material consideration.

The stone surrounding these irregular deposits is often of a very hard and siliceous character and full of loughs, rendering the operation of driving very slow and expensive. It may be here stated that the cost of driving a limestone-drift varies greatly, and ranges from 13s. to 40s. per foot, while a shale-drift may be driven at a cost of from 7s. to 16s. per foot.

As the development of the mine goes on, the workings will consist of a number of ramifications through the limestone.

Sometimes the connexion between one large pocket of ore and another is by a gut of ore of considerable size. These guts are usually enclosed between two stone backs forming the sides, and by an irregular roof and sole.

If any ore is left in the bottom of the first workings, a downward or dip working is made, and in the event of its continuance or further

development, the shaft is deepened and another level driven out. In this way it may be found necessary to drive a series of levels, one below the other, from the same shaft. In the event of the ore, cut by the first level, exhibiting a marked extension upwards, and necessitating the use of a number of hoppers or hurries before it can be conveyed to the shaft, it is often found advisable to set off an upper level from the same shaft, or should the distance be too great, to sink a new shaft from the surface.

Careful timbering is also required in the working of this class of ore, more especially if the pockets are of large dimensions. In the working of some of the smaller pockets, where the enclosing stone is of a hard nature, no timber may be required. Small guts in this kind of ground are worked as far as possible, from the dip to the rise, and are subject to similar nips and enlargements as those accompanying other forms of deposits. The guts usually run parallel to the main faults nearest to them, and often continue for considerable distances.

The workings are first carried to their farthest extension, and any ore left in the roofs, soles, or sides, is stripped off from the inside outwards. The taking out of pillars and middlings left in the mine after the ore-bearing area has been worked over, is carried on in a similar manner to that already described in dealing with bed-like deposits.

The irregular masses of ore in the old and new No. 1 pits, and the No. 4 pit of the Montreal mines, may be mentioned as one of the largest deposits of this kind in the district. An immense quantity of hæmatite of good quality has been raised from these mines during the last thirty years, and although the three forms of deposit are found in the royalty, by far the largest proportion has been obtained from the irregular deposit. Other deposits, such as High House and Crossfield No. 2 pit, have also been of an extensive character.

Figs. 5, 6, 7, 8, and 9 (Plate IV.) are plans of an irregular deposit and show the first workings therein at different levels. Fig. 10 (Plate IV.) is a section of the same deposit through the line E F.

Surface Deposits.

A notice of the workings of the various kinds of hæmatite deposits would scarcely be complete without touching upon surface deposits, as these, although coming under the category of irregular deposits, are sometimes worked opencast—a system of working which will only require brief notice.

This form of deposit usually occurs along the outcrop of some of the principal faults, or in dish-like undulations, in close proximity to these

faults. Some of them lie immediately under the gravel or Boulder Clay, termed the surface.

The deposit is worked as follows:—After the extent and nature of the deposit has been ascertained, the surface is stripped off the ore for a distance of from 10 to 12 feet clear of the outer edge of the deposit all round, the sides of the cast being well battered or sloped back. The deposit is then worked as a quarry, one side being first sunk so that a series of bench-workings can be carried on. The ore is drawn to the surface by means of an engine-incline, or by a portable engine from a shallow shaft, with drift-connexion to the bottom of the deposit. If the ore is of great thickness, a series of drifts may be required.

The principal opencast mines in the district have been those of the Cleator Iron Ore Company; Nos. 1 and 8 opencasts of the Crossfield Iron Ore Company; and Mr. Stirling's open-workings in the Montreal and Todholes royalties. In the case of the Crossfield and Montreal opencasts much difficulty has been experienced in the working of the ore, owing to the close proximity of the river Keekle, the bed of which had to be boxed or troughed over. This stream in wet weather is liable to sudden and heavy floods from its extensive watershed, although in dry seasons it contains very little water. It may be of interest to mention that the inside bottom width of this troughing is 20 feet, top width 29½ feet, and the depth 9 feet. The total length of the troughing in the two royalties is 1,584 feet. The first troughing was put in by the Crossfield Company in 1878.

Mining Requisites.

It now remains to describe a few of the principal mining requisites used in working the mines.

Timber.—English, Scotch, and Irish larch, peeled and unpeeled, is used for headtrees, legs, and general propping; while round or square Norway and Swedish timber is also used, the round sometimes for legs and props (but seldom for headtrees) instead of the larch, in places where the crush or overhanging weight is not excessive. Square Norway timber is used for building wooden pillars or splitting up into coverwood, wedges, etc. Boards (termed coverwood) of either home or foreign timber from 5 to 12 inches wide, and from 1 to 2 inches thick, are used for covering the top of the larch sets, while the small ends of the larch-trees as well as small foreign timber (termed poling) are also used for this purpose in places where the ground is of a loose or broken character. Poling and coverwood are sometimes used together.

Rails.—The rails used underground for bogie roadways are either the bridge or angle-plate sections weighing from 5 to 6 pounds per foot.

Bogies.—Both steel and wood bogies are in use, mounted either with flanged wheels made of cast-steel and about 12 inches in diameter for the bridge-rails, or with edge-wheels for the angle-plate rails. Different methods are adopted for fixing the wheels and axles. In some cases, the axles are fixed and the wheels run loose. In others, one wheel is fixed on the axle and the other is loose; and again sometimes both wheels and axles run loose. The length and width of a bogie at its centre capable of holding 10 cwts. of ore is 2 feet 7 inches by 1 foot 10 inches, and the height 1 foot 7 inches. They are, however, made of various sizes to hold from 8 to 12 cwts. of ore.

Jumper Steel.—As the great bulk of the ore in all parts of the district has to be blasted, it is of importance that a good and reliable steel be used. Twenty years ago nothing but double-shear steel of the best quality would stand the crucial test of boring through some of the harder ores and keeping an edge. For some years past, however, a cast steel has been introduced, which is equally applicable to the requirements of the district, and can be supplied at less than half the previous cost. The steel bar used is $\frac{7}{8}$ inch in diameter, round or octagonal (the former section being now most largely used). The length of the jumper varies from 1 to 4 feet.

The rate of progress made in jumper-boring varies with the hardness of the ore, and many cases occur where it would be considered a good day's work to bore 3 feet. On an average, however, a good miner will bore from three to four holes, averaging 2 feet in depth per shift.*

Explosives.—A great stride was made in developing and working many of the harder ores of this district, when dynamite and other kindred explosives were introduced. The sinking of shafts, and the driving of wet or damp stone-drifts and ore-workings, were much more laborious and lengthy operations in the days when nitro-glycerine compounds were unknown than they are now; and, as a consequence of the use of dynamite, some mines and a number of workings in most mines which were abandoned owing to their being unworkable to profit with powder, were recommenced, and in many cases with good results.

The different kinds of nitro-glycerine preparations in use at the present time are:—(1) dynamite; (2) gelignite; (3) gelatine-dynamite; and (4) blasting-gelatine.

The second and third varieties are, however, most largely used, being

* Mr. J. D. Kendall's *Iron Ores of Great Britain.*

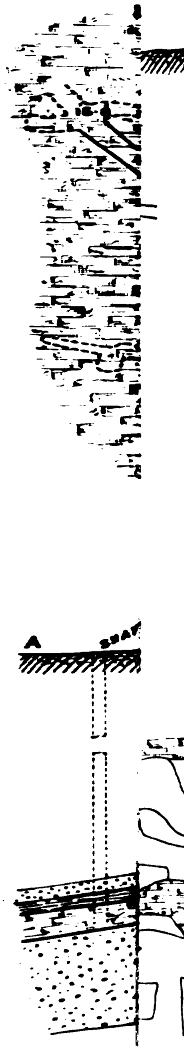
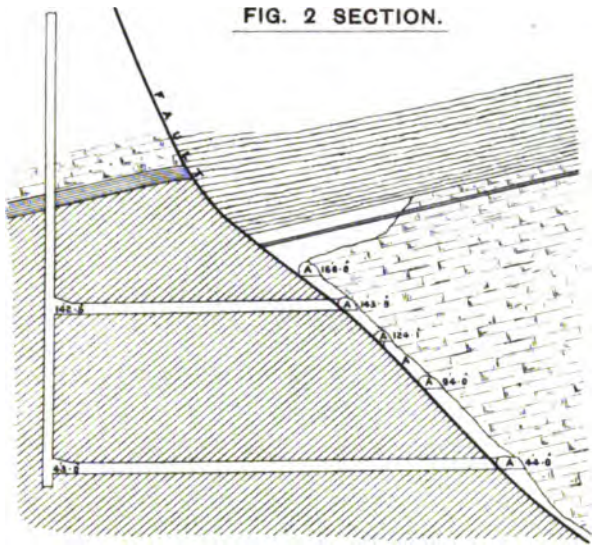
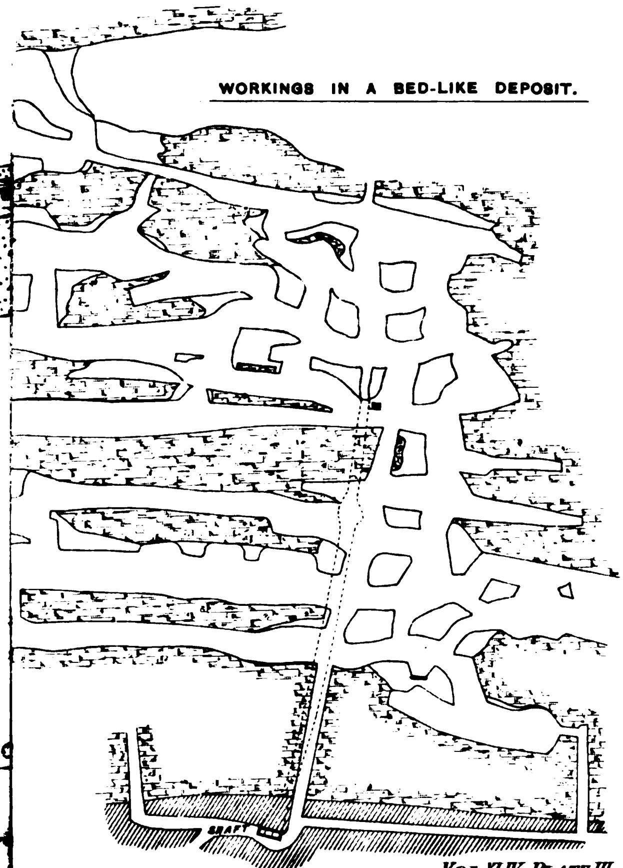


FIG. 2 SECTION.



WORKINGS IN A BED-LIKE DEPOSIT.



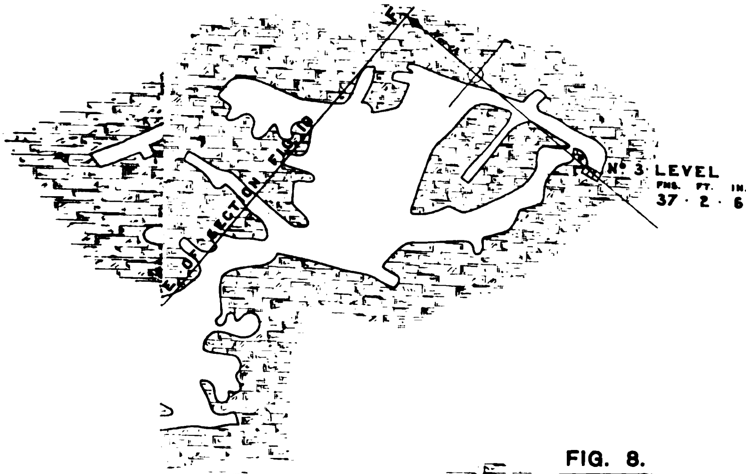
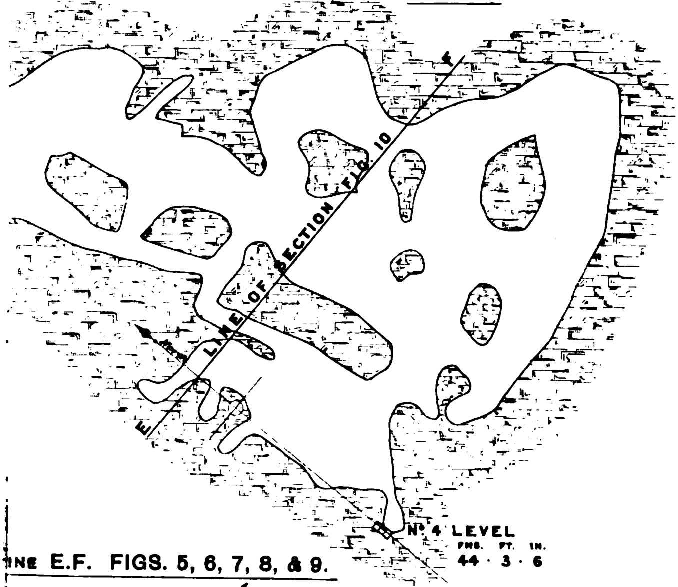


FIG. 8.



INE E.F. FIGS. 5, 6, 7, 8, & 9.

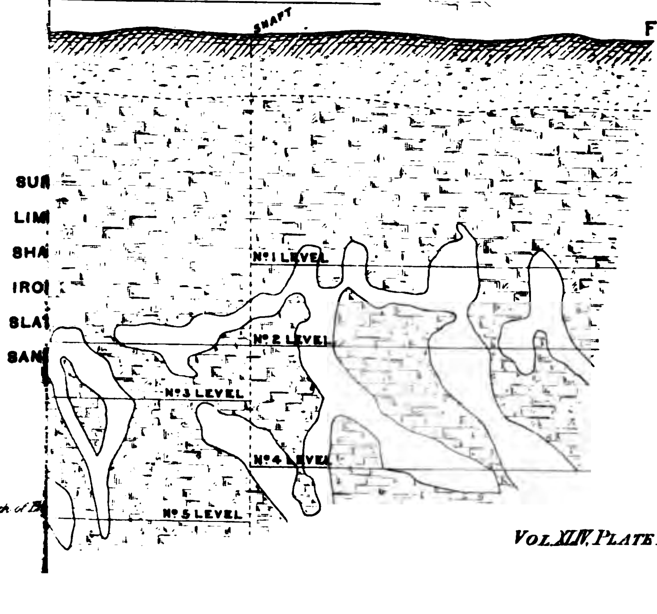
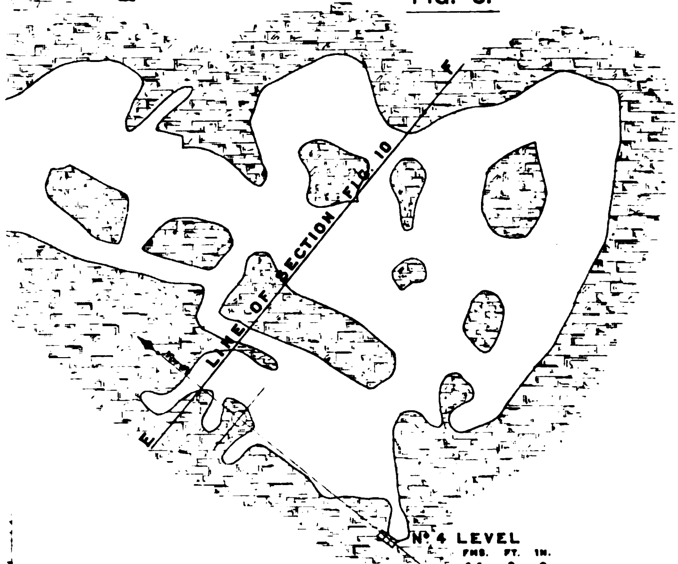
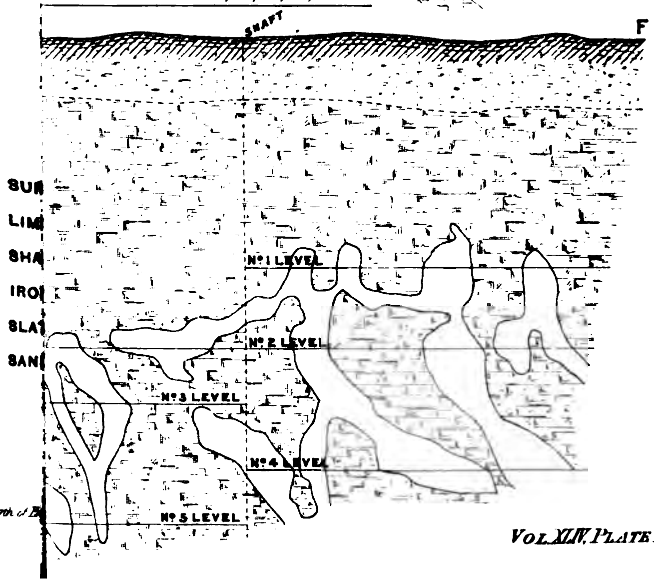


FIG. 8.



LINE E.F. FIGS. 5, 6, 7, 8, & 9.



considered stronger than the ordinary dynamite. Lithofracteur, gun-cotton, tonite, and oarite have also been used in the district to a limited extent. Very little blasting powder is now used.

As previously stated, the great bulk of the ore requires to be blasted; but there are instances known to the writer, notably at the Southam mines, in the neighbourhood of Bigrigg, where a large proportion of the ore can be got with the pick. This of course reduces the cost of working the ore very materially. Cases of this kind are, however, very rare.

The detonators or caps used to explode dynamite charges are partially filled with fulminate of mercury, the quantity varying with the particular compound which they are intended to explode, quadruple or quintuple detonators being used with gelatine-dynamite, and sextuple with blasting-gelatine. The gutta-percha fuze fits exactly into the cap, the end resting on the top of the fulminate. In the case of damp holes, the cap and the part of the fuze connected with it are well covered with grease and nipped tightly together; the latter is usually done in all cases. Nippers are supplied for this purpose, but the miners sometimes compress the top of the cap with their teeth—a most dangerous operation.

Candles.—The candles used are the ordinary dip tallow candle, numbering from 14 to 16 in the pound. A piece of plastic clay is put round the bottom of the candle, and by this means it can readily be made to adhere to any portion of the working-face in any position; or it can be stuck on the front of a bogie, thus giving a good light to the trailer behind.

All the miners are strongly prejudiced in favour of the use of candles, and it would be difficult to convince them that oil or tallow lamps stuck in the cap, collier-like, are better adapted for use in metalliferous mines.

The attempt made in the foregoing paper has only been to give a general idea of the usual methods adopted in working these ore-deposits. To have dealt with the subject *in extenso*, and made reference to all the varying conditions which are met with in the development and working of some of the mines, as well as to have embraced the question of contending with the water-feeders and the pumping appliances in use for this purpose, would have necessitated a treatise of much greater length, and one altogether outside the scope of this paper.

The following paper by Mr. H. MELLON on "The Mining of the Softer Ores of Furness" was then read:—

THE MINING OF THE SOFTER ORES OF FURNESS.

BY H. MELLON.

The district of Low Furness is bounded by the sea on three sides, and rising gently from the sea-level, it forms a piece of fine undulating country from 100 to 300 feet above sea-level, backed in the north by the hills of the Lake District.

On reference to a geological map of the southern portion of Furness, it will be seen that on the north are the Silurian rocks, then follows an irregular belt of Carboniferous Limestone, about five miles wide, stretching right across the district from east to west, this is followed on the south by the Yoredale Shales, Magnesian Limestone, and New Red Sandstone.

The rock-formations, except at a few places, are obscured from view by a thick covering of sand, gravel, and Boulder Clay. The latter is locally known as pinnel. The hæmatite deposits occur at the junction of the Carboniferous and Silurian rocks, on the line of faults, in wide fissure-like receptacles, and in irregularly-shaped dish-like hollows or caverns in the limestone immediately under the drift-covering. It is in this latter form that most of the softer ores of the district are deposited. The importance of the hæmatite deposits may be inferred from the fact that the quantity of ore annually raised in the district is about 900,000 tons, fully three-fourths of which is of the softer variety.

The limestone is thick-bedded, and has only a few thin partings of shale. It attains a great thickness southwards: thus, at Stainton 950 feet has been bored through. With one or two exceptions, which are on the line of great faults, the principal deposits of ore that have been so far discovered are confined to the north-western portion of the district, nearest to the site of the great elevatory movement, which brought up the rocks of Haume.

The deposits are not confined to any particular geological horizon, as there are deposits in the upper, middle, and lower beds of the limestone series. The deposits vary much in size, the largest discovered being at Park. It is of very irregular form, and measures about 1,500 feet in length from east to west, by 750 feet wide, and is proved over 600 feet

in depth; from this single deposit some millions of tons have been raised; other deposits contain thousands of tons, while there are small ones containing only a few hundred tons.

The general character of the softer ores is a confused mass of rough, fragmentary pieces of hard hæmatite, embedded in a matrix of softer ore, with which are mixed, to a greater or less extent, quartz, calcite, and clay. On the sides and floors of the ore-receptacles, and embedded in the ore, are large masses of vari-coloured clay and sand, with occasional blocks of country rock.

Some of the first deposits worked were no doubt discovered by their outcrop, others were exposed by the ploughshare or in cutting drains. In many places rude implements and other traces of ancient mining have been discovered, proving that these deposits have been worked from very early times.*

In searching for the deposits, it is usual either to bore by hand, or to sink small shafts through the drift in order to find where the ore comes to the surface of the limestone. The covering on the limestone averages from 30 to 70 feet in thickness. It is very difficult ground to bore through, on account of the many large and hard boulders that are met with; moreover boring may, to a certain extent, be misleading if not properly conducted, as the surface of the limestone is full of fissures, many of which are filled with ore, some perhaps only a few inches wide. If these were bored into by anyone unacquainted with the nature of the ground very erroneous conclusions might be drawn. The average cost of boring through this superficial covering is from 25s. to 30s. per fathom.

When there is little or no water, as very often happens, and the depth to the rock is not more than 60 or 70 feet, small trial-shafts (4½ feet square inside of frames) may be put down by windlass.

These are more satisfactory than boreholes, as on reaching the rock, drifting, for a short distance, may be carried out in various directions and the strata properly explored. To successfully carry out these explorations it is necessary to have a knowledge of the direction of the main dislocations and jointings of the strata; and if the comparatively small area which some of the deposits occupy be considered, the necessity for such trials being made, so that no large area is left unexplored, will be recognized.

The simple method of sinking by windlass and bucket is found to be the cheapest and best for a depth of 60 or 100 feet. These trials are

* A full description of the geology, history, and nature of mining in Furness, is contained in the *Iron Ores of Great Britain*, by Mr. J. D. Kendall.

quickly made, and the plant and materials are inexpensively moved from place to place. The cost is from 10s. to 12s. per foot, labour and materials included.

On ore being proved by one of the shafts, working is commenced at once. If the ore be found by boring, a shaft is sunk similar to the trial-shaft, and a level driven out into the ore.

The exploring-levels are kept small (6 feet high by 5 feet wide) and well timbered. The levels are put out in any direction that the irregularities of the roof and other interruptions will permit, a wheelbarrow and running-planks being used to convey the material to the shaft-foot, where it is filled into the buckets and wound to the surface. Winding by hand-power may be superseded by horse or steam-power. Horse-gins are still in existence in the district: they serve the purpose well for winding by bucket at these temporary shafts, which become twisted and crushed in all directions on the removal of the ore around them.

On the introduction of the horse-gin or other winding power, the drifts while in ore are opened up to the ordinary size of 9 feet high by 8 feet wide.

The diagrams (Figs. 1 and 2, Plate V.) show a plan and section of a typical soft-ore deposit in the limestone. The first levels (Fig. 2) from the gin-pit are shown interrupted by the irregularities of the roof. The pit is sunk deeper, and in the next levels the area of the deposit may be sufficiently proved to decide that a more permanent shaft must be put down, with suitable machinery. The site selected, taking into consideration the surface conveniences, is outside the area of the deposit, and far enough back from the edge, so as to be outside the area of the ground that may be drawn when the surface subsides.

The shaft is usually of rectangular form: 14 feet by $4\frac{1}{2}$ feet, inside of frames, is an ordinary size. This is divided into four compartments, two cage-ways, a ladder-way, and space for pumps. The frames and dividings are set either "skin to skin" or 20 inches apart, and backed by $1\frac{1}{2}$ inches boards. The first sinking may be for 120 feet, at which a level is driven out to the ore, and communication made with the gin-pit for ventilation. From this level "rises" are put up at convenient points to the level of the gin-pit workings. When the rises are to form a hopper (to deliver the ore by) and ladder-way, the usual size is 6 feet by $4\frac{1}{2}$ feet inside of the frames; but when it is required to send out by these rises, as is often the case, particularly from the first drifts or opening-levels, any sand, clay, or other matter separate from the ore, a larger-sized rise is required. The higher portions of the ore are worked out first.

The drifts will vary in height according to the height of the ore, and if the covering is a strong Boulder Clay, only very light timbering is required to support the roof; but if a sand or gravel roof, strong and careful timbering is needed. After the uneven portions are worked out the drifts of the usual size (9 feet by 8 feet) are made.

The first levels of a new height are driven out in various directions from the rises to the boundaries of the ore, leaving pillars of irregular size and shape; these are afterwards worked or robbed out, commencing at the outside, leaving behind the embedded masses of clay, sand, and stone where possible. When the ore at that height is exhausted the levels of another height or layer is commenced: thus a slice 9 feet in thickness over the area is taken out each time, the sole of the last height being the roof of the following. The plan (Fig. 1, Plate V.) shows this irregular form of pillar-and-stall working.

The great pressure of the superincumbent pinnel, etc., crushes down the timber as each height or tier is worked out, the broken timber and *débris* forming the roof of the next tier of workings.

The engine-shaft may be sunk in the first intance 200 or 250 feet, or it may be sunk an additional 60 feet, the usual depth between the levels driven out from the shaft at a time as required. Rises are put up in the ore each time to the levels above. After a few heights of ore have been worked out indications of the subsidence will appear on the surface, the removal of the ore round the gin-pit will cause it to collapse, and it may be necessary to sink another shaft, outside of the area of the deposit, for the purpose of ventilation.

From the time that the subsidence shows at the surface, the full weight of the surface-covering is carried on the timber of the workings. The timber largely used for prop-wood is larch, cut to lengths of props 7 feet, and headpieces 8 feet long: the diameter is from 5 to 10 inches, the heaviest and best timber being selected for the main roads. Two props and a headpiece form a set: these are fixed 21 inches apart and covered on the top with redwood boards, called "spiles," in lengths of 4½ feet by 4 or 5 inches wide by 1 inch thick (Figs. 3 and 4, Plate VI.).

When the forebreast of the drift has advanced 4 or 5 feet beyond the last set of wood, two sets are fixed, the boards are then driven in, one at a time from behind, by placing the end on the top side of the head of the first set fixed: one man holds down the front end of the spile, while the other drives it up from behind until it is even on the underside of the previous timbering. In the case of a loose friable top, the wood is kept

close up to the forebreast, and spiles are driven over each set, boards or slabs being placed at the back of the props to prevent the sides falling.

Some of the ore is very friable and quickly falls on exposure to the air and damp. In the first drifts, and where there is no roof pressure, boards are simply laid on the heads in the ordinary way.

On driving through masses of very fine wet sand or soft clay, special timbering is required to meet the pressure in every direction, rough hay and brushwood being used for packing to prevent the sand from running.

Main levels under great pressure in wet ground soon require extra timbering. On the first signs of any movement, additional props and heads lining sets are put in between those already fixed: the drift is then what is called close-wooded. After that additional props may be fixed under each head, resting on sole-pieces; the drift is then close-wooded and double propped (Fig. 5, Plate VI.). Occasionally the sole of the drift has to be boarded and sole-trees put in to prevent creep.

The ore is mainly got with the pick, occasional shots are put in to assist the getting by simply driving in a bar about 2 feet; the bar is provided with an eye by which to withdraw it, and the shot is usually put in near the top of the forebreast, the ore being first undercut in the sole.

The ore-pillars are worked out by taking off a drift-width at a time from the side.

On driving the first levels of each height, any sand, clay, or stone met with is sent out of the pit to the spoil-bank; after the opening-levels have been driven, any clay or sand, etc., is thrown back into the goaf. In the case of fine sand, the floor is first covered over with slabs and boards to prevent it from giving trouble in the next lower tier of workings. In this way the ore is worked out, commencing at the top of the deposit and taking horizontally slice after slice, 9 feet in thickness, until the deposit is exhausted.

Skilled miners are not required to simply use the pick and shovel, but it is requisite that they should understand how to place and fix the timber to keep the workings safe.

The prop and cover-wood being cut to standard sizes, the drifts should also be kept of uniform size. At some of the mines the prop-wood is prepared by special men, that is, it is hollowed out, or as it is termed collared, to receive the head-piece or collar, giving it a bearing the full width of the prop. When men prepare this wood for themselves they very often, to spare time, cut the end of the prop in a wedge shape, then

hollow it, giving the head a mere knife-edge to bear upon. (Fig. 6, Plate VI.).

Two men are employed in each drift, and they put their ore to the shaft-foot, or into the rise if not more than 150 feet distant. A small district is usually allotted to a company of men who may have three or four drifts in connexion with a rise. A trailer runs the ore from the rise to the shaft. Two men can put out from 5 to 6 tons net per set on an average, taking the driving of the first headings with the robbing out of the pillars. Contracts are often let, at a price per ton, to take out the whole of the ore over a fixed area for a single height of workings.

The average cost of the labour of getting and delivering the ore at the shaft is 1s. 9d. per ton net; and at this price men earn 5s. per set. The cost of timber is a heavy item in this class of mining: taking one deposit with another, it averages from 6d. to 8d. per ton of ore. The other charges are much the same as in other classes of iron-ore mining.

Strong wood-framed waggons, made to take into parts for convenience of getting up and down rises, are usually used in the rise workings; on the main drawing-levels ordinary sheet-iron waggons are used, containing from 8 to 12 cwts. each. The underground roads are made of the usual flat-bottomed rails or angle-plates laid to a gauge of 21 inches.

The ventilation of these mines is usually very good. By natural means, a good circulation is maintained when two shafts are connected.

In the case of only one shaft, it is usual to make one compartment of the shaft (connected with the higher levels) the upcast: this is assisted by a fire pan or steam jet. Small quantities of gas are occasionally met with on the re-opening of old workings: the gas is doubtless generated from the decomposition of the timber.

The drainage of these mines is generally a light matter, but there are exceptions where the ore deposits are of greater depth and on the lines of faults. The limestone being very cavernous, the rainfall quickly passes away. Many of the mines on the higher elevations are practically dry except during excessive rain, then the drainage-area, formed by the subsidences, collects the water in large quantities, which finds its way into the mine at a greater speed than the natural drainage can carry it off. To collect and divert all the water possible from the drainage-area of a mine is important; but it is a matter that is often neglected. The cost of mining this class of ore in the wet state is often more than double that of getting it dry: extra timber is required, there is more loss, and the ore is more difficult to separate from the impurities, consequently it is of inferior quality and of less value.

The quality of the softer ores differs considerably in the various deposits as well as in different parts of the same deposit. An average sample gives the following analysis :—

Silica	20·00
Alumina	1·50
Iron peroxide	71·50
Lime	·80
Magnesia	Traces
Sulphur	"
Phosphoric acid	"
Manganese dioxide	2·70
Loss by calcination	3·50
	100·00

The metallic iron at 212 degs. Fahr. is about 50 per cent.
The moisture averages from 8 to 12 per cent.
The specific gravity is 3·80.

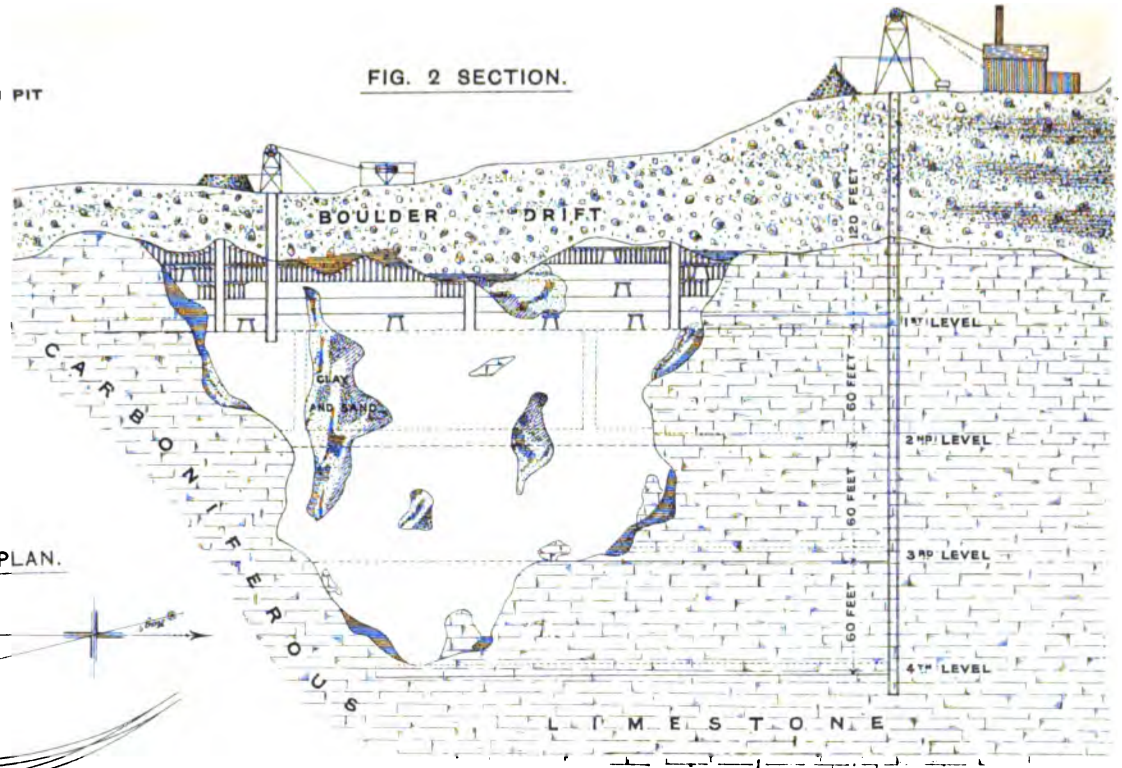
During the past few years some of the inferior qualities of the softer ores have been treated by machinery, the most successful appliance being the Kennedy and Green ore-washer. This machine is in daily use at the Park and Roanhead mines. The ore treated contains from 35 to 38 per cent. of silica, and a large amount of clayey matter. In carrying out this process the ore is put into a revolving-sizer, by which it is disintegrated and washed : the rough portions fall upon a picking-table to be hand-picked ; while the finer portions being sized, are jigged or washed in the ordinary way. The ore falls upon a perforated tray in a box which is full of water. Connected with this is a piston, which causes the water to quickly rise and fall, the lighter matter is carried off by the flowing water, and the ore falls through the perforated tray into a box, the trays being covered with a layer of washed ore "bedding" of a larger gauge than the perforations. This machine can wash from 8 to 10 tons per hour. A more expeditious and less costly process of treatment for raising the quality of the poorer ores would be of great benefit to the district.

As regards the future, there are doubtless many deposits, both of the richer and poorer ores, still to be found in this large area which has been practically unexplored.

To illustrate Mr. H. Mellon's Paper on "The Mining of the Softer Ores of Furness."

FIG. 1 PLAN.

FIG. 2 SECTION.



Scale 100 Feet to 1 Inch.

Andrew Reid & Co. Ltd. Newcastle on Tyne.

To illustrate Mr. H. Mellon's Paper on "The Mining of the Softer Ores of Furness."

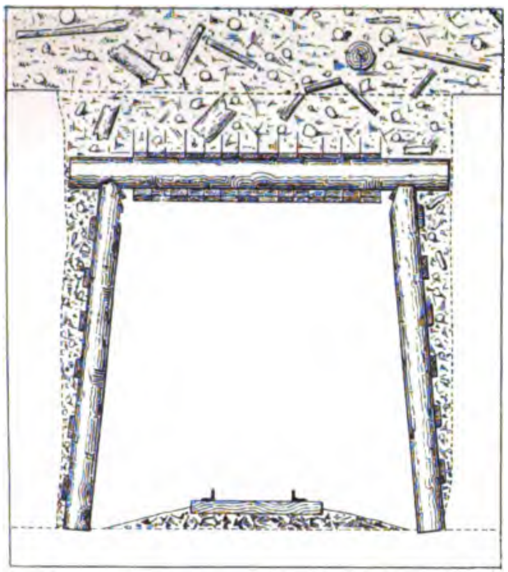


Fig. 3. Cross Section.

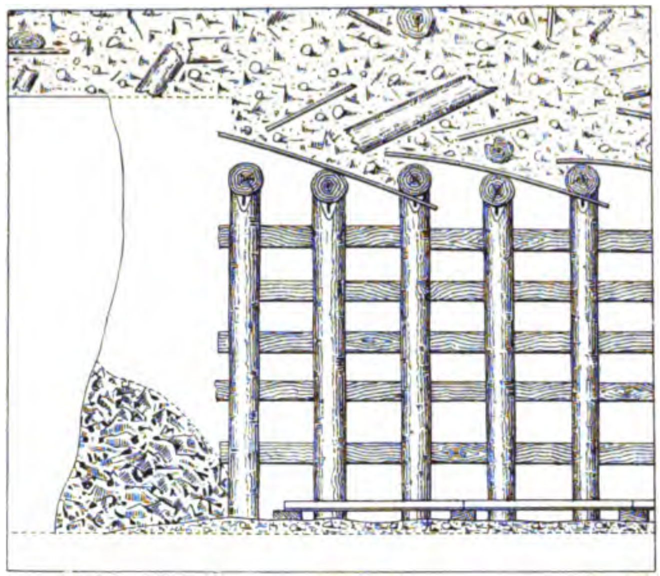


Fig. 4. Longitudinal Section.

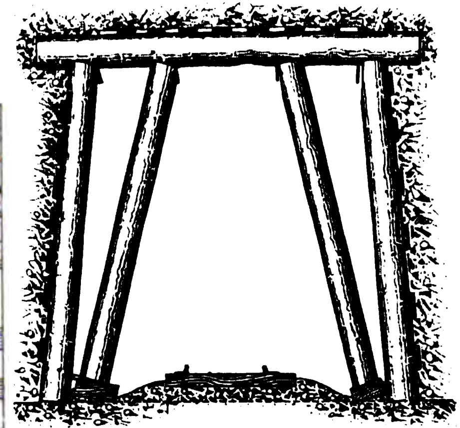


Fig. 5.

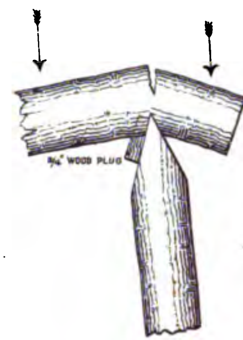


Fig. 6.

Scale - 4 Feet to 1 Inch.

North of England Institute of Mining & Mechanical Engineers
Transactions 1884-5

Andw Reid & Compy Ld Newcastle on Tyne

DISCUSSION ON MR. W. C. BLACKETT'S PAPER ON "THE COMBUSTION OF OXYGEN AND COAL-DUST IN MINES."*

Mr. H. HALL (H.M. Inspector of Mines) wrote that he had had an opportunity of inspecting and attending the inquest as to the Albion colliery disaster. This explosion was undoubtedly due to coal-dust, ignited by firing untamped dynamite shots, used to blow down roof timbers in a main intake airway (with 30,000 cubic feet of air passing per minute). This main intake was very dry and dusty, as were all the others in the colliery, with one exception. The explosive force and fire passed throughout the main intake airways, travelling over 4 miles in length. In each district the blast travelled inbye with the wind, increasing in violence as it passed forward, until it was able to distribute itself in the working-places, and there apparently dying out. The one wet district in the colliery alone escaped the blast; and the men in that district would have been saved had they not attempted to escape and met the after-damp—the horses stayed near the faces and took no harm.

Mr. W. N. ATKINSON (H.M. Inspector of Mines) wrote that Mr. Blackett's paper was a thoughtful and valuable contribution to the much debated subject of explosions in coal-mines. There was, however, one point, referred to in different parts of the paper, to which he could not subscribe; that being the reason assigned for an explosion failing to traverse certain of the roads in a mine. The following extract from the paper referred to this point:—"There is no turning to the right or left, and no going through doors or stoppings into the returns; but as the explosion passes, down go these obstacles, beyond which, however, the road is not prepared, and therefore the explosion does not extend therein."† The subject is also referred to in connexion with certain roads not traversed by the explosions at Seaham and Usworth collieries. No doubt the "pioneering phenomena" spoken of by Mr. Blackett are essential conditions in the propagation of an explosion by coal-dust, but doors or ordinary stoppings would not arrest that process; they are blown out before the flame of the explosion reaches or passes them, and are frequently demolished at places never reached by the flame. Mr. Blackett recognizes that there may be other factors—in the quantity and quality of the dust—on the roads not traversed by the explosion; and he believed these to be true and sufficient reasons for the facts observed. He (Mr. Atkinson) had never observed an instance where a door or unstowed stopping had appeared to arrest the progress of an explosion when there was a supply of coal-dust on the

* *Trans. Fed. Inst.*, vol. vii., page 54.

† *Ibid.*, vol vii., page 56.

road on both sides of the door or stopping. That the progress of an explosion was frequently arrested near stoppings, and sometimes near doors, was due to the fact that the quality of the dust was frequently different on the opposite sides of the stoppings and doors, and not to any effect which an unstowed stopping or door had in preventing the "pioneering phenomena" described in the paper.

Mr. T. Forster Brown wrote that he held the opinion, dating from 1882, that with a blown-out shot in a main intake airway in a colliery where the dust was dry and fine (and, of course, pure coal-dust), it was not necessary that fire-damp should be present for an explosion to occur. His conversion to this opinion was due to the second explosion at Risca colliery in 1882, where an explosion occurred in the main intake airway, about 450 feet from the downcast shaft, where 80,000 cubic feet of air per minute was passing, and no possibility of fire-damp being present. The explosion travelled all through the colliery, damaged the ventilating fan at the surface, killed four shot-firers and all the horses in the mine. Since that date he had insisted upon dust being watered in all the steam-coal collieries with which he was associated.

Mr. Thomas Douglas said the members were all fully alive to the great importance of this question, and the fact that a Royal Commission had recently reported and made a valuable report in reference to it would excite interest in the matter for some time to come. Some of the members might be a little indisposed to agree that the greater proportion of explosions were due to coal-dust, but they would all be of one mind that coal-dust was a very important factor.

Mr. W. C. Blackett, referring to the remarks of Mr. Atkinson, admitted that the "pioneering phenomena" could only conduct the explosion along such galleries as contained a quantity and a quality of dust sufficient to develop combustion: and the main difference between himself and Mr. Atkinson was that the latter gave prominence to the quantity and quality of the dust, he (Mr. Blackett), while fully recognising this statement, gave additional reasons why certain roads were selected by the blast, and more particularly instanced the travelling-road at Seaham colliery. He (Mr. Blackett) believed that doors and stoppings had considerable effects in the guidance of a dust-explosion.

THE BRUNSVIGA CALCULATING-MACHINE.*

The Brunsviga calculating-machine performs addition, subtraction, multiplication, and division mechanically. The ordinary machine will give products not exceeding thirteen figures, or dividends not exceeding

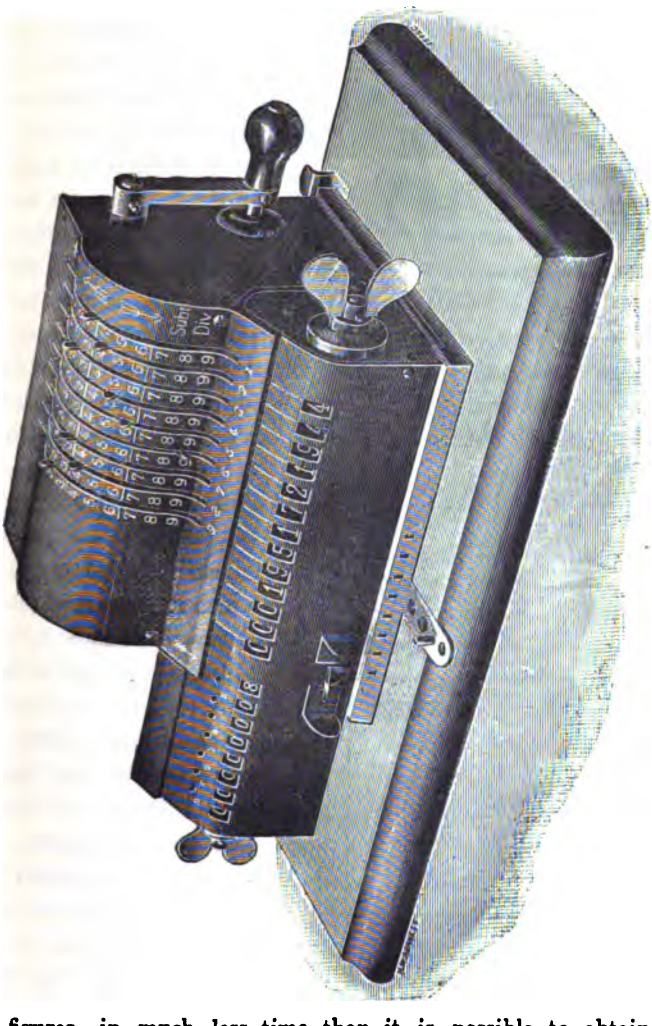


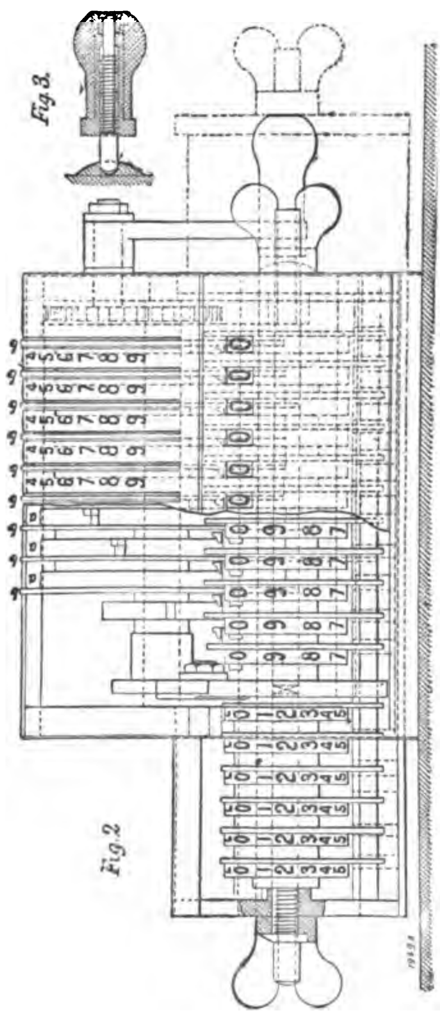
Fig. 1.

eight figures, in much less time than it is possible to obtain them by ordinary calculation. The large machine gives products up to eighteen figures. Its general appearance is shown in Fig. 1, whilst the details of its construction will be understood from Figs. 2, 3, and

* The illustrations are reproduced by consent of the proprietors of *Engineering*.

4. The operations of the machine are based on mechanical addition. Thus, to multiply by six, the quantity in question is added six times to itself.

The handle shown to the right of the machine (Fig. 1) turns a small spur-wheel which gears with a second, keyed on the main shaft of the machine, on which are also keyed a number of discs marked *a* in Figs. 2 and 4. Of these discs there are nine, corresponding to the nine slots shown in the upper part of the frame of the machine. Levers project through these slots, one to each of the nine discs. The handle being at rest in its normal perpendicular position (Fig. 1), if a lever is moved opposite any one of the numbers at the side of its slot, a corresponding number of teeth are caused to project from the previously smooth edge of the disc to which it is attached (Fig. 4). If now the handle be turned through a complete revolution, this disc revolves with it, and the projecting teeth move one of the number-wheels below into such a position that a figure corresponding to the number set by the lever appears at one of the openings below.



To multiply by 2, the handle is turned round twice; by 3, three times, and so on; the number of revolutions of the handle being automatically registered at the small openings shown on the left side of the machine. To multiply by 27, the handle is turned round seven times, thus multiplying by 7, and then the sliding block carrying the

number-wheels is moved a space to the right, as indicated by the dotted lines in Fig. 2, and the handle turned round twice. The operation is, in fact, identical with the process employed in ordinary arithmetic. The figures 27 will now appear in the number-spaces to the left of the sliding block (Fig. 1), and the product at the large openings to the right.

In performing division, the operation is the inverse of this, and the handle is turned round in the opposite direction, thus subtracting the numbers set by the levers instead of adding them.

If by error, the handle has been turned in the wrong direction, the revolution must be completed, and the mistake rectified by turning the handle in the opposite direction.

When setting the levers, the handle must always be placed in its proper position. To ensure this, a stop is attached to the side of the machine, and the handle is fitted with a spring-latch (Fig. 3), which holds it securely in the proper position, whilst any desired numbers are being set by the levers

The principal part of the mechanism is the series of discs carrying the movable teeth. Their construction is shown in Fig. 4, where *a* is the disc, and *b* is the lever which is set opposite the desired number on the frame. This lever is a projection upon a slotted plate, having a cam-groove *c* in it. In this groove lie pins, secured to the movable teeth, which run in slots, in the main disc. When the slotted disc is moved relatively to the main disc, a greater or smaller number of the pins pass into the outer portion of the slotted groove, and a corresponding number of teeth project from the main disc. A triangular stop fitting into the angular notches on the movable disc ensures that the disc stops in such a position with respect to the main disc that the movable teeth are either in or out, and that none project half-way.

Were it not for the necessity of "carrying" from one number wheel to another, no further device would be necessary; but when one number wheel is at 9, any further addition involves the carrying over of one unit to the next wheel. For this purpose each main disc carries two other teeth (one at either end of the row of nine principal teeth), which are used for the "carrying." In subtraction one of these teeth is used, and in addition the other. These teeth project permanently from the edge of the disc, but are held by a spring out of line with the main teeth, and so pass on one side of the teeth operating the number-wheels. When, however, a number-wheel is at 9, a cam connected with it comes into such a position that, on any further rotation of the wheel, a stop is caused to project, and gets in behind the carrying tooth of the next disc, pressing it

into line with the main teeth, so that it is brought into gear with the teeth driving the next number-wheel, which it accordingly turns through one division, and the "carrying" is effected.

Any number recorded on the number-wheels can be quickly cancelled by turning round the thumb-pieces shown at either end of the bar carrying the number-wheels. The thumb-piece on the right (Figs. 1 and 2) cancels any numbers appearing at the large openings, whilst that on the left performs the same operation for those appearing at the small openings. For this purpose the shaft on which the number-wheels are mounted is capable of a slight axial movement, but is normally kept from so moving by a spring. It has projecting from it a number of pins, one of which is shown at *d* (Fig. 4). These pins, when the shaft is in the working position, do not prevent the rotation of the number-wheels, which are cut away so as to afford a free space for these pins. When, however, the shaft is moved outwards a small distance, the pins come into contact with stops on the number-wheels, and carry these latter round with them, and when the shaft has finished its rotation each wheel shows zero at the openings.

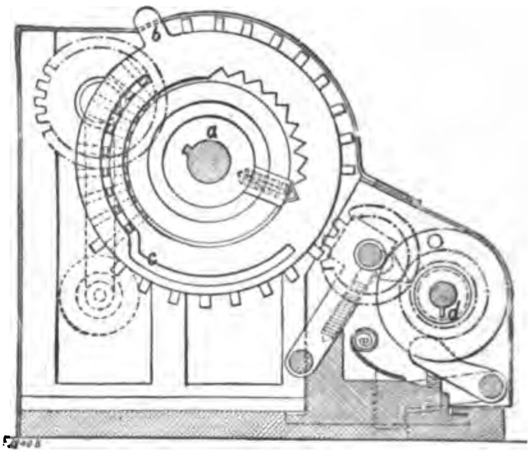


Fig. 4.

By means of a frame and gearing, three Brunsviga calculating-machines may be worked simultaneously by one operator, or one or two machines may be used as desired. Each machine can also be removed from the frame and used singly.

The machine is applicable to decimal calculations, no regard being made to the decimal point, which can be placed in position in the product, by the usual rules.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
HELD AT THE INSTITUTE ROOMS, BARNSLEY, JULY 25TH, 1894.

MR. W. E. GARFORTH, RETIRING PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. THOS. BARRON, Colliery Manager, Rylands Main Colliery, Barnsley.
Mr. A. HORSFIELD, Mechanical Engineer, Horbury Junction Ironworks, Wakefield.

Mr. H. B. Nash and Mr. R. Turnbull were appointed scrutineers of the voting papers for the election of officers for the year 1894-95, and of the balloting lists for representatives on the Council of The Federated Institution of Mining Engineers for the year 1894-95.

The SECRETARY (Mr. T. W. H. Mitchell) read the Annual Report of the Council as follows:—

THE COUNCIL'S ANNUAL REPORT.

The Council have pleasure in handing the members of the Institute their report on the work of the past year.

The number of members on the books of the Institute at the end of the year was 4 life members, 18 honorary members, and 219 ordinary members. This is an increase of 1 in the number of life members and 29 in the number of ordinary members.

The following is a comparative summary of the number of members for a few recent years:—

	1891-2.	1892-3.	1893-4.
Life Members	3	3	4
Honorary Members ...	18	18	18
Ordinary Members ...	172	190	219
Totals	193	211	241

The following papers have been read during the past year:—

"The Best Means of Conveying Electric Energy in a Fiery Mine." By Mr. A. W. Bennett.

"Arrangements for Lighting and Re-lighting Safety-lamps by Electricity." By Mr. W. Best.

"Safety-catches in Connexion with Mining Cages and Hoists." By Mr. A. Casely.

"The Victoria Friction-clutch." By Mr. L. Dobinson.

"Coal-dust in Mines and its Relation to Explosions." By Mr. C. Dunbar.

"Presidential Address." By Mr. W. E. Garforth.

"The Lührig System of Coal-washing." By Mr. G. B. Walker.

The following papers were also contributed to the Leeds meeting of The Federated Institution of Mining Engineers:—

"The Baum Coal-washing Machinery." By Mr. F. Baum.

"The Oil-shale Industry of France." By Mr. G. Chesneau.

"The Transmission of Power by Compressed Air." By Prof. Goodman.

"Spontaneous Combustion in Coal-mines." By Mr. W. S. Gresley.

"Notes upon a Practical Method of Ascertaining the Value or Price to be Paid for Zinc Minerals" By Mr. H. D. Hoskold.

"Photography in Mines." By Mr. Herbert W. Hughes.

"Geology of the West Yorkshire Coal-field." By Prof. Lupton.

"Obituary of Thos. W. Embleton." By Mr. T. W. H. Mitchell.

"The Friction of, or Resistance to, Air-currents in Mines. Appendix." By Mr. D. Murgue.

"The Coal-fields of Sonora, Mexico." By Mr. James Overend.

"Notes on Coal-getting by Machinery." By Mr. T. H. Wordsworth.

The arrears of subscriptions on June 30th, 1894, amounted to £25 10s., being £3 12s. in excess of last year; and of the £21 18s. arrears existing on June 30th, 1893, £17 13s. has been recovered during the year 1893-4.

A call of 2s. per member was made by The Federated Institution of Mining Engineers for the year 1892-3, and a further call of 2s. per member has been made for the year 1893-4. This increased call renders it imperative that members should remit their annual subscriptions when due, to enable all calls to be duly met.

Five meetings have been held during the year, and in February last a meeting of The Federated Institution of Mining Engineers was held in Leeds.

By the kind permission of the proprietors the West Riding and Silkstone, Normanton; St. John's, Normanton and Middleton Main collieries, near Leeds, were open for inspection of the members; also the following works in Leeds:—Messrs. John Fowler & Co., Steam Plough Works; Messrs. Kitson & Co., Airedale Foundry; Messrs. Hudswell, Clarke & Co., Railway Foundry; Mr. Alf. Cooke, Crown Point Printing Works; Messrs. Hathorn, Davey & Co., Sun Foundry; Messrs. Greenwood & Batley, Albion Works; and The Leeds Forge.

It is with great regret that the Council have to call the attention of the members to the scarcity of papers, and they are convinced that if the members realized the importance of keeping together this and similar institutions, by placing on record their individual experience for the instruction of the junior members, they would make a special effort to contribute papers, and thereby increase the usefulness of the Institute.

The members will have noticed in the *Transactions* a memoir of Mr. T. W. Embleton, who was thrice President of this Institute. At a meeting held on April 7th, a resolution was passed placing on record the members' appreciation of Mr. Embleton's past work in building up and increasing the usefulness, not only of the Midland Institute of Mining, Civil, and Mechanical Engineers, but of The Federated Institution of Mining Engineers and other scientific societies.

Mr. Nevin moved the adoption of the report. He hoped that all the members would consider the penultimate paragraph of the report and assist the Institute by adding to the number of papers.

Mr. W. Hoole Chambers seconded the motion, which was carried.

ACCOUNTS.

Mr. H. B. Nash (one of the Auditors) read the statement of accounts for the year ending June 30th, 1894, as follows:—

THE TREASURER (MR. T. W. H. MITCHELL) IN ACCOUNT WITH THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS, 1893-94.

DR.

Date	Particulars	£ s. d.	£ s. d.
1893.			
July 1.	—To Balance at Bankers	23 7 8	
"	" Cash in Treasurer's hands ...	2 14 11	
			26 2 7
1894.			
June 30.	—To Subscriptions for 1893-94 ...	286 10 0	
"	" " paid in advance for 1894-95	4 10 0	
"	" Arrears	17 13 0	
"	" One Life Member	20 0 0	
			328 13 0
"	" Sale of Dinner Tickets		7 19 0
"	" " *Transactions*		0 18 0
"	" Members' portion of the Wine Account at the Annual Dinner		2 8 0
"	" Sale of Federated Institution Dinner Tickets, Leeds Meeting	23 0 0	
"	" Members' portion of Wine Account	6 10 0	
			29 10 0
"	" Bank Interest		0 17 8
			£396 8 3

July 19th, 1894.

Audited and found correct, { H. B. NASH. E. W. THIRKELL.

CR.

Date	Particulars	£ s. d.	£ s. d.
1894.			
June 30.	—By Federated Institution of Mining Engineers:—		
	Call of 15s. per Member on 217 Members for 1893-94...	162 15 0	
	Special Call for 1892-93 ...	18 18 0	
"	By Excerpt *Transactions* ...	14 19 8	
			196 12 8
"	" Annual Dinner		13 18 6
"	" Printing and Stationery		9 4 2
"	" Office Rent		12 0 0
"	" Reporter		6 10 0
"	" Insurance		1 11 6
"	" Cleaning		3 10 0
"	" Gas Company		0 3 4
"	" Hire of Rooms for Meetings in Leeds and Sheffield		1 15 6
"	" Secretary's Salary	£25 0 0	
"	" " Expenses ...	14 13 4	
			39 13 4
"	" Leeds Meeting of The Federated Institution of Mining Engineers:—		
"	Dinner	33 14 9	
"	Reporting Proceedings ...	2 10 0	
"	Use of Oxy-Hydrogen Lantern	0 15 0	
			36 19 9
"	" Stamps, Telegrams, Carriage, Wrappers, Post Cards, and Sundries		14 7 4
"	" Balance at Bankers	£58 17 9	
"	" Cash in Treasurer's hands ...	1 4 5	
			60 2 2
			£396 8 3

Midland Institute of Mining, Civil, and Mechanical Engineers.

General Statement, 1893–94.

Liabilities.

	£	s.	d.
1894. June 30.—None.			
Balance, being capital	448	3	2
	£448	3	2

Assets.

	£	s.	d.	£	s.	d.
1894. June 30.—By Cash in Bank	58	17	9			
" " " Treasurer's hands ...	1	4	5			
				60	2	2
" " Estimated Value of Instruments for Fan Experiments				14	0	0
" " Value of *Transactions*, 6,817 parts at 1s. each	345	17	0			
" " 18 Copies of French Commission Report on the Use of Explosives, at 3s. each	2	14	0			
				348	11	0
" " Arrears of Subscriptions				25	10	0
				£448	3	2

Audited and found correct,

July 19th, 1894.

H. B. Nash,
E. W. Thirkell, } Auditors.

Mr. NASH said the accounts showed that the financial position of the Institute was in a very satisfactory condition, and that Federation had not only been a benefit in the increased information and papers received, but also in the cost of printing the papers, which, although it included the cost of printing the whole of the *Transactions* of The Federated Institutes, cost less than their own *Transactions* cost when they worked independently. They had £448 3s. 2d. of capital, without any liabilities, irrespective of the value of the books in the library. The Institute was consequently in a good financial position, and was advancing in membership as well. He moved that the accounts and balance-sheet be adopted.

Mr. J. NEVIN seconded the motion, saying it was the most satisfactory balance-sheet that the Institute had ever had.

The motion was carried unanimously.

ELECTION OF OFFICERS.

The Scrutineers reported the result of the election of officers for the year 1894-95 as follows:—

PRESIDENT.

Mr. JOHN NEVIN.

VICE-PRESIDENTS.

Mr. W. HARGREAVES. | Mr. H. B. NASH. | Mr. JNO. LONGBOTHAM.

COUNCIL.

Mr. A. A. ATKINSON.	Mr. M. HALL.
Mr. J. E. CHAMBERS.	Mr. F. J. JONES.
Mr. W. HENRY CHAMBERS.	Mr. A. B. SOUTHALL.
Mr. W. HOOLE CHAMBERS.	Mr. E. W. THIRKELL.

SECRETARY AND TREASURER.

Mr. T. W. H. MITCHELL.

The CHAIRMAN said that he had pleasure in vacating the chair in favour of Mr. Nevin. He was sure that he expressed the opinions of all the members when he said that they wished Mr. Nevin a good term of office, and assured him that he would have the hearty support of the Vice-Presidents, Council, and members.

Mr. JOHN NEVIN, on taking the chair, said he was much obliged to the members for the honour they had done him in electing him President of the Institute. He would do his best for the interests of the Institute, and felt sure that the Vice-Presidents, Council, and members would afford him the same assistance as they had done to his predecessors in that office for the benefit of the Institute.

Mr. H. B. NASH moved a vote of thanks to the retiring President, and said that the members were all sorry to lose Mr. Garforth from that position. During the two years Mr. Garforth had held office, the status of the Institute had been greatly advanced.

Mr. J. E. CHAMBERS seconded the motion.

The PRESIDENT had great pleasure in supporting the motion. During Mr. Garforth's term of presidency, they had held their own with the other institutes.

The resolution was carried by acclamation.

Mr. GARFORTH thanked the members for their vote of thanks. He thought that he ought rather to thank them for their great kindness to him during the past two years. He was anxious, at the time of the visit of The Federated Institution of Mining Engineers that their Institute should make that visit as successful as the meetings which had been held in other districts; and from the expressions he had heard, not only in Leeds when the papers were read, but from the gentlemen who visited the collieries, he thought they had been as successful. It was very satisfactory to know that during his presidency the membership of the Midland Institute of Mining, Civil, and Mechanical Engineers had increased from 172 to 219—say 20 per cent.—in two years. He attributed that increase to the fact that the *Transactions* of The Federated Institution of Mining Engineers were becoming so valuable that no one who wished to keep pace with the science and practice of mining could do without them. He moved that a vote of thanks be given to the Secretary for the way in which he had performed his duties.

Mr. W. HOOLE CHAMBERS, in seconding the motion, said it was a pleasant duty to be Secretary to an Institute which was prospering. Mr. Mitchell had given good support, and a great amount of work to the Institute, and had efficiently filled the office he held; and trusted that he might be spared many years to carry on those duties with success to the Institute.

The resolution was carried unanimously.

The SECRETARY, in thanking the members for the kind resolution, said that as they helped each other the Institute would prosper, but he could do little unless the members contributed papers.

Mr. ROUTLEDGE proposed a vote of thanks to the Vice-Presidents and Council.

Mr. TURNBULL seconded the motion, which was carried.

Mr. R. ROUTLEDGE read the following paper on "Damage done by Lightning to the Surface Works at Garforth Colliery":—

DAMAGE DONE BY LIGHTNING TO THE SURFACE WORKS AT GARFORTH COLLIERY.

By R. ROUTLEDGE.

The Isabella and the Sisters pits, both drawing coals, are 2,400 feet apart, the latter being the upcast shaft. The air-compressing plant is situated at the Sisters pit, and is available for both shafts, the air being conveyed by pipes, 7 inches in diameter, on the surface, to the Isabella pit, and down that shaft into the workings.

On May 31st, 1894, a thunderstorm occurred from 2 to 3 p.m. The chimney at the Sisters pit is 103 feet high, 12 feet in diameter at the bottom and 7 feet at the top (outside measurement), and is fitted with a copper-tape lightning-conductor. At 2·50 p.m. lightning struck the chimney, broke the copper-tape about 4 feet from the top, lifted the ground to a depth of 1 foot where the end of the conductor had been run to earth, and broke one of the air-pipes, lying at a depth of 2 feet and 12 feet distant from the chimney. The chimney itself was not damaged.

The winding-engineman was affected as the last cage-load of workmen was being drawn to bank; fortunately he was just able to land the cage before he dropped into his chair. The following is his statement:—Thomas Teale, winding-engineman, states that "whilst he was drawing a rope of men at 2·50 p.m. he received a shock from the handles of his engine. He believes if he had been wishful to let go the handles of his engine he would have been unable to do so. The crash of thunder and flash were simultaneous, and he had a strange feeling, and thought he was done for, and for a moment lost his senses and dropped; he was shaken from head to foot, and next day the muscles of his arms were very stiff."

Amos Dickinson, banksman, who was on the flat-sheets at the surface, states that "after hearing the report, similar to several cannons going off together, he distinctly saw a ball of fire go down the pit."

Ed. Sibary, the hanger-on, states that "he had sent up the cage containing men, and the other was coming down steadily, when he observed a ball of fire. He is not sure whether it struck the cage or the flat-sheets. There was a loud report as of cannon going off, and the porch was lit up for some yards. The flash then went into the workings along the signal wires."

John Toes, the horse-keeper, was a few yards from the pit-bottom, and states that "he distinctly saw the flash pass."

At 1,500 feet from the pit-bottom there is a junction or centre for electric signalling. A man is kept at this point to signal inbye and to the hauling-engineman on the surface. There is also a telephone connected with the lamp-cabin on the surface and with the writer's office near the Isabella pit. The instruments at the junction underground and the lamp-cabin were destroyed.

John Dobson, bye-workman, states that "he was sitting beside John Brown, the signalman, about 2·50 p.m., when he distinctly saw a flash of fire pass along the wires."

Mr. A. W. BENNETT said that this serious accident appeared to have arisen principally if not entirely from the lightning-conductor having become disconnected. The lightning-conductor was put up for the express purpose of carrying off electricity in case of a storm, by offering a path of such low resistance that other bodies offering greater resistance took practically none of the electrical charge. In this instance, when the flash took place the lightning-conductor would receive a large charge of electricity, and the corroding action of the current might break the conductor at the faulty part; the circuit thus broken might develop an enormous current in any surrounding medium which was a moderately-good conductor, such as the electric signal-wires and compressed air-pipes. By this means an enormous current would be induced. Probably part of the primary current might go through these channels instead of through the lightning-conductor. The telephone could be safeguarded by lightning-conductors; but he did not think they were much good, as he had had instruments with and without these conductors damaged by lightning. The moral, if there was one, would be: that wherever there was a lightning-conductor it should be examined, and tested regularly for continuity. There were three telephones—one at Mr. Routledge's house, one at the lamp-room, and one at the junction: in the second and third the wire of the bell and the wire of the secondary circuit were burnt through inside the instrument, but that at Mr. Routledge's house was uninjured.

The CHAIRMAN asked how many ampères would pass?

Mr. BENNETT replied that it was impossible to answer that question.

The CHAIRMAN asked if there was a simple coupling which would prevent the electricity from entering the mine?

Mr. BENNETT said it might be possible to prevent the current from entering the telephone. But it would be better to have the telephone

burnt out, than the pit set on fire. It might give a certain amount of safety.

The CHAIRMAN suggested that if the current could have been prevented from going beyond the sump, the danger would have been prevented.

Mr. W. HOOLE CHAMBERS thought that the connexion with the earth was at fault. If the coupling at the top of the chimney had kept good there would have been a much more violent current at the bottom of it. The current was conducted into the earth within 7 feet of the pipes, which he considered to be too great a distance for a current of that description to be taken to a conductor so good as the pipes. No doubt it was important to test the lightning-conductors on chimneys. At the Thorncliffe collieries the conductors were tested every twelve months. Where electric signals and telephones were in use, it was important to have the lightning-conductor so placed that it would not affect them.

Mr. ROUTLEDGE said that the conductor was carried under the ground within 6 inches of the pipes.

Mr. J. E. CHAMBERS said he supposed Mr. W. Hoole Chambers meant that the electricity was conducted by the air-pipes in the direction of the mine?

Mr. ROUTLEDGE said that the pipes which were broken did not go down the Sisters pit, but to the other pit.

Mr. J. E. CHAMBERS asked what was the distance of the telephone from the line of pipes?

Mr. ROUTLEDGE said that the telephone-wires did not go near the air-pipes.

The CHAIRMAN asked whether the current went in the direction of the telephone?

Mr. ROUTLEDGE said that they thought so, because they were destroyed, whilst the signal wires were not injured.

Mr. NEVIN asked what arrangement there was at the end of the conductor to spread the current?

Mr. ROUTLEDGE said there was a copper plate 2 feet square.

Mr. NEVIN said the damage at that point seemed to have been caused by the current leaping from the conductor to the air-pipe.

The CHAIRMAN said, after reading the Final Report of the Coal-dust Commission, he was exceedingly anxious that no fire of any kind should get near the main haulage-road in the pit under his charge.

Mr. BENNETT said that in this case it would have been better had connexion been made with the air-pipes, but he did not think it would have

made much difference. His idea was that the connexion being severed the lightning took the alternative course. In the case of factories, it was customary to put all the machinery in actual connexion with the conductors, so that any lightning might be taken away from them.

Mr. W. Hoole Chambers did not say that the accident had occurred by the lightning-conductor not being in connexion with the air-pipes ; what he wished to infer was that the current which had passed through the lightning-conductor had not been properly conducted to earth, or they should not have had the damage which had occurred. Whether that conduction should be made in connexion with the metal pipes or not was a matter of question. The metal pipes were damaged, and if the current had been properly conducted to earth the damage would not have occurred. There should be careful consideration as to the method in which the earth-connexion was made with the lightning-conductors, because they knew that the strain upon the conductor must be enormous in such cases. It was desirable also that the conductors should be tested as to their capacity of carrying off the lightning current. He did not think any method could be adopted to obviate the fact that telephones and electrical apparatus were susceptible of great disturbance during storms. Cases had occurred where, close to excellent conductors, the lightning had struck, disarranging the apparatus and everything else. They could not say where the lightning would strike, but they should ascertain that their conductors were in the best position, and that they were capable of leading away the currents.

Mr. Childe asked whether the lightning went down the rope ?

Mr. Routledge said that he was not sure whether it went down the rope or down the cage-conductors.

Mr. Childe asked if the lightning had made a connexion with the electric signals at the surface ?

Mr. Routledge answered that he could not say.

Mr. Childe said perhaps the same flash that struck the chimney had struck the head-gear.

Mr. Routledge said no doubt that was so. The men in the lamp cabin heard a great noise.

Mr. Childe said it looked as if the rope had been struck, as the engine-man received a shock.

The Chairman said that he was more inclined to believe that rather the rope was struck and took the current down the pit than that the bad conductor was struck.

Mr. T. W. H. Mitchell asked if Mr. Routledge was sure that the conductor was struck ?

Mr. ROUTLEDGE said he was satisfied that the lightning-conductor was struck, or the earth would not have been torn up and the air-pipes broken.

Mr. W. HOOLE CHAMBERS said Mr. Routledge's remark showed the earth-conductor was not what it should have been, or it would not have torn it up.

Mr. ROUTLEDGE said the ground was wet at the time. The chimney was built on a seam of coal. He did not know whether that would have any effect.

Mr. NEVIN said part of the current seemed to have struck the pulleys, one portion going down the shaft, and the other portion passing into the engine-house.

Mr. BENNETT said with reference to two points being struck at once : Suppose they had a certain electric potential between two points, and several paths for the electricity to travel along—one path with one ohm of electrical resistance, another path of two ohms, a third of a hundred ohms' resistance: then the path of a hundred ohms' resistance would only take a small portion of the current. The potential would be very little upon it, because the greater quantity would travel on the one ohm conductor. But, suppose they disconnected the one ohm conductor, then the electricity would take the hundred ohm conductor. It seemed to him that this might have happened in the present case.

A vote of thanks was accorded Mr. Routledge for his paper, and the discussion was then adjourned until the next meeting.

REPRESENTATIVES ON THE COUNCIL OF THE FEDERATED INSTITUTION OF MINING ENGINEERS FOR THE YEAR 1894-95.

The Scrutineers reported the result of the ballot as follows:—

Mr. A. M. CHAMBERS.	Mr. JOS. MITCHELL.
Mr. W. E. GARFORTH.	Mr. JNO. NEVIN.
Mr. J. LONGBOTHAM.	Mr. C. E. RHODES.

The annual dinner was afterwards held at the Queen's Hotel.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING AT THE HATTON WATERWORKS, JULY 18TH, 1894.

THE HATTON WORKS OF THE STAFFORDSHIRE POTTERIES WATERWORKS COMPANY.

The Potteries Waterworks Company obtained their first Act of Parliament in 1847, taking powers to raise capital and take 1,500,000 gallons of water a day from springs at Wall Grange, subsequently acquiring other rights at the Meir and Stockton Brook, whereby their powers of production were greatly increased.

In 1888, the company again went to Parliament to obtain powers for further increasing the supply of water for the Potteries and Newcastle-under-Lyne district. It was decided to select a position in the Hatton Valley at a point mid-way between Whitmore and Standon Bridge railway-station, on the Swynnerton estate. They obtained powers to acquire the land at Hatton, and lay mains to Hanchurch, and construct a reservoir, continuing the mains thence through a portion of Trentham and Hanford to Trent Vale. In the prior tests two boreholes, 12 inches in diameter, had been made to a depth of 500 feet into the New Red Sandstone formation, terminating in an almost impervious conglomerate. The yield of water from these two boreholes, which were about 300 feet apart, was over 1,500,000 gallons a day, flowing naturally at the surface of the ground.

The necessary works were commenced without delay, and in the course of two or three years the supply became available for public use. A main, 16 inches in diameter, was laid from Hatton to the top of the Hanchurch Hills, where an extensive reservoir was constructed, and whence a connexion was made with the mains at Trent Vale. At the present time another main, 20 inches in diameter, is being laid from Hatton to the reservoir.

The engine-house at Hatton is a lofty structure of buff bricks, with red-brick facings, ornamental stonework also being introduced. Accommodation is provided for two compound vertical beam engines.

There are four steel boilers, 30 feet long and 8 feet in diameter.

A well is sunk 15 feet in diameter, and the water is pumped from that station to the reservoir at Hanchurch, a distance of 2 miles, with a rise of 372 feet.

The reservoir is constructed entirely of cement concrete, and is arched over and covered with earth. It is 215 feet long by 155 feet 6 inches wide; when filled it has a depth of water of 15 feet, and is capable of containing 3,000,000 gallons. The company has constructed a water-tower near Swynnerton Hall for the supply of the mansion-house and the village. The tower is an ornamental erection, and is used as an observatory.

DESCRIPTION OF PUMPING-ENGINES AT THE HATTON PUMPING-STATION OF THE STAFFORDSHIRE POTTERIES WATERWORKS COMPANY.

BY T. M. FAVELL, ASSOC. M. INST. C.E.

The engines consist of two sets of compound beam rotative pumping-engines of similar sizes, the only difference being that they are made right and left-handed respectively. (Figs. 1 and 2, Plate VII.)

The high-pressure cylinders are 32½ inches in diameter and 52 inches stroke, and the low-pressure cylinders are 48 inches in diameter and 84 inches stroke. All the cylinders are steam-jacketed. They are carried on strong cast-iron girders, fixed to concrete pillars for foundations. The pillars are faced with brickwork.

The steam valves are slide-valves, with Mayer cut-off attached to the high-pressure cylinders.

The beams each consist of two flitches of mild steel 2 inches thick, 24 feet 6 inches in length between centres, and 26 feet 3 inches over all, and 4 feet deep at the centre. They are fitted with steel gudgeons, and all the bosses are riveted on. The total finished weight of the beams is 10 tons each.

The fly-wheels are 20 tons each in weight, 18 feet in diameter, and are made with a spur rim into which gears the driving-wheel of a Galloway barring-engine which is used for starting the pumping-engines. The barring-engine drives the fly-wheel until such time as the steam, acting in the main engine cylinders, causes the fly-wheel to overrun the speed of the barring-engine, and the pinion of the barring-engine is then thrown out of gear.

The crank-shaft and fly-wheel are placed within the full length of beam, so as to allow of the well-pumps being of the same stroke as the low-pressure cylinders.

The well-pumps are plain bucket-lifts 18¾ inches in diameter, and were at first fitted with ordinary butterfly flap-valves, but it was found that the pressure of water on them was so small (only about 30 feet) that they did not close properly till the engine commenced its downward

stroke, and caused a jar on the engine. They were then fitted with double-beat valves, which were found to work in a very satisfactory manner.

The engines are fitted with governors, not intended to regulate the speed, but only to stop them in case of an accident to the main, or anything causing the engine to exceed a speed of 14 revolutions per minute. In this case a valve is tripped and the steam shut off from the engine.

The water from the well is delivered by the well-pump into a tank in which is placed a surface-condenser, consisting of 300 brass tubes, 1 inch in outside diameter, and 7 feet 3 inches long, over which the water flows on its way to the ram-pumps. The steam circulates inside the tubes, and the condensing water on the outside. A very steady vacuum is maintained, and the temperature of the water from the well is not perceptibly increased by being used for this purpose.

The air-pump is fixed directly under the high-pressure cylinder, and is of the same stroke (52 inches), and is worked direct from the piston-rod of the high-pressure cylinder.

The forcing-pumps consist of a barrel 18½ inches in diameter, adapted for a stroke of 7 feet, placed under the low-pressure cylinder, and fitted with a piston and ram connected direct to the piston rod. The diameters are arranged so that one-half of the water is pumped in the upstroke and one-half in the downstroke of the engine, the whole quantity of water being drawn through the suction-valve in the upstroke and forced through the delivery-valve in the downstroke, but half of the water returns on to the top of the piston in the downstroke, and is displaced in the upstroke.

A third valve placed on the delivery-main is used as a retaining valve, so that the pump-valves and packing-rings of the pump can be examined without emptying the air-vessel. All the valves are double beat, 18 inches in diameter, and interchangeable both as to valves and seats. They are faced with a white metal, consisting of a mixture of tin and zinc, which is found to resist wear very well.

All the pump-work is subject to a working pressure of 180 lbs. per square inch, and was tested to 300 lbs. per square inch before being erected. The pump-ram is fitted with gun-metal rings, and had steel coils on the Mather & Platt system fitted to them, but it is now found that they work better without these coils.

The air-vessels are 19 feet in height and 3 feet in inside diameter. They are supplied with air, when working, by admitting a little into the pump every stroke by a self-acting valve. For charging the air-vessels

after it has been necessary to have had them emptied, they are supplied from a Westinghouse engine and air-pump, which has been found to work in a most satisfactory manner.

The boilers of Lancashire type are four in number, each 8 feet in diameter, 30 feet long, and fitted with six cross-tubes in each flue. A steam receiver is fitted to them, and separate pipes from it supply each engine with steam at a working pressure of 80 lbs. per square inch. The feed-water is supplied direct from the main. A feed engine has been fitted, but it is never used.

The engines were intended to pump 1,500,000 gallons of water per day against a total head of 520 feet, being 150 feet in the well and 370 feet from the surface of the ground to the reservoir at Hanchurch Hill. They are forcing the water, as intended, but the lift in the well is at present only about 30 feet. The delivery of the ram-pump is 80 gallons per revolution, the calculated quantity being slightly over this (82 gallons). The barrel of this pump is 18½ inches in diameter, the stroke 7 feet, and the well-pump is 18¾ inches and same stroke, so that the ram-pump is always kept solid.

The speed of 14 strokes per minute yields 1,120 gallons per minute or 1,612,800 gallons per day of 24 hours, and there is no difficulty in running at a higher speed when only one engine is working.

At present there is only one pipe-main to the reservoir, 18 inches in diameter; this is rather small for two engines working together, and a second main of 20 inches in diameter is now being laid, so that there will be a main for each engine, but the arrangements will be such that either engine can pump into either main.

When running at 14 revolutions per minute, the indicated horse-power is 166, giving a useful efficiency of nearly 84 per cent. The coal consumed in one month has been weighed, and from a calculation of the quantity of water pumped, based upon the revolutions as shown by the counter on the engine, the duty is about 60,000,000 foot-pounds per cwt. of slack used. This is a very good result, when it is remembered that only slack of a very ordinary quality was used, that cold water was used to feed the boilers, and that the trial was made in the course of the ordinary working, this result being a much better guide as to the efficiency than a special trial where everything is looked after in a special way, which is impossible under ordinary working conditions.

The engines were used for the temporary pumping required during the sinking of the well. It is very doubtful if any other form of engine than a rotative beam-engine would have been so well adapted to this

purpose. When the sinking with the engine commenced, it had only to run at a speed of 4 revolutions per minute to keep the well dry, but the speed was increased to 22 revolutions per minute when the well was sunk to its present depth of 110 feet, and before the crut to the borehole was commenced. During the time the sinking was in progress it was necessary to pump some of the water to the reservoir. This was done during the time when the men were not working in the well, and therefore the sinking was not carried on continuously day and night, so as to allow of this being done.

Considerable difficulties were encountered in the sinking of the well, owing to the nature of the rock passed through, as it yielded large quantities of sand, which was pumped with the water. This unfortunately caused considerable damage to the working-barrels, rams, and valves of the forcing-set of pumps of the engine used for pumping from the well, and of the one which was used to pump to the reservoir. The condenser well was several times filled with sand, the vacuum was destroyed, and the well had to be cleaned out before this could be restored.

The whole of the engines and pumps were designed by the writer, and constructed and erected by Messrs. G. Kirk & Co., with the exception of the well-pumps which were fixed by the water company.

To illustrate Mr T. M. Favell's "Description of Pumping Engines &c."

Fig. 1.

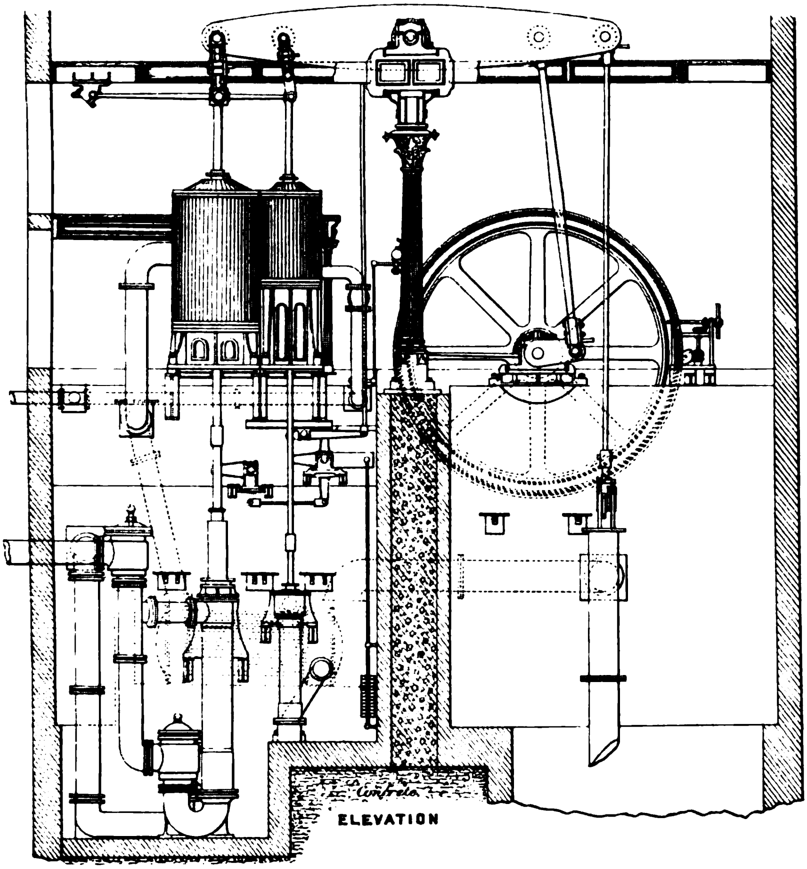
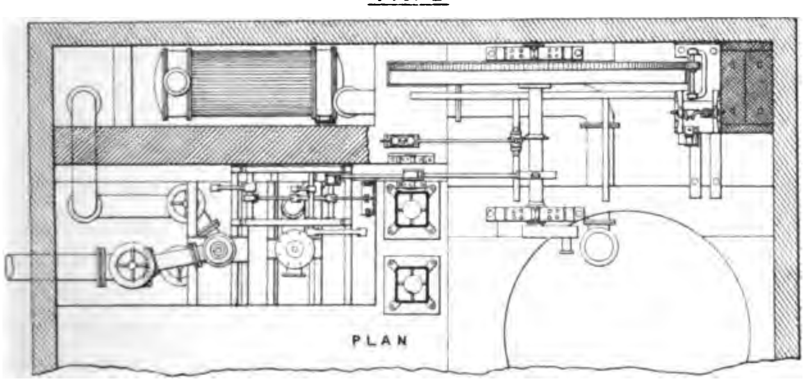


Fig. 2



Scale 12 Feet to 1 Inch

Andw Reid & Compy Ltd Newcastle-on-Tyne

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

ANNUAL GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
ON SEPTEMBER 5TH, 1894.

MR. ARTHUR SOPWITH, RETIRING PRESIDENT, IN THE CHAIR.

The SECRETARY read the Annual Report of the Council as follows:—

THE FIFTH ANNUAL REPORT OF THE COUNCIL.

The Council are once more enabled to congratulate the members upon the success and increasing strength of The Federated Institution of Mining Engineers.

The Institution is intended to further the advancement of the sciences of mining, geology, metallurgy, engineering, and their allied industries, by the interchange of opinions, and by the reading of communications from members and others. Its prosperity could be materially increased by the members promoting its claims and advantages, and extending the membership.

The members receive the papers read at the meetings of the Federated Institutes, and participate at the two General Meetings held in each year in the various mining districts of the United Kingdom, and at the one held annually in London.

The influence of the Institution as representing mining engineers in their entirety would become materially effective, and the value of the *Transactions* be greatly enhanced if it included all the societies interested in mining, metallurgy, and their allied industries.

The large number of members resident in India and the Colonies might hold meetings, and the papers communicated and the accompanying discussions could be sent for incorporation in the *Transactions*.

The Institution now comprises six societies, viz.:—The Chesterfield and Midland Counties Institution of Engineers; the Midland Institute of Mining, Civil, and Mechanical Engineers; the Mining Institute of Scotland; the North of England Institute of Mining and Mechanical Engineers; the North Staffordshire Institute of Mining and Mechanical Engineers; and the South Staffordshire and East Worcestershire Institute of Mining Engineers.

The number of members on the register since the formation of the Institution are:—

Year.	No. of Members.	No. of Non-Federated.
1889-90	1,189	50
1890-91	1,187	9
1891-92	1,414	19
1892-93	1,533	19
1893-94	2,068	123

The status of the admission of members of the Federated Institutes has been considered, and the desirability of adopting a classification of their members, in accordance with Bye-law 8, is urgently suggested.

General Meetings have been held during the year in London, Scotland, and Yorkshire, and the members are to be congratulated upon the value of the papers communicated and the accompanying discussions. The thanks of the Institution have been conveyed to the gentlemen who kindly allowed their works and collieries to be visited by the members during these meetings.

Presidential addresses have been delivered during the year to the members of The Federated Institution of Mining Engineers by Mr. Arthur Sopwith; the Chesterfield and Midland Counties Institution of Engineers by Mr. William Spencer; the Midland Institute of Mining, Civil, and Mechanical Engineers by Mr. W. E. Garforth; the Mining Institute of Scotland by Mr. G. A. Mitchell; and the North of England Institute of Mining and Mechanical Engineers by Mr. A. L. Steavenson.

The following papers have been read upon geology:—

"The Formation of the Earth's Crust and its Destruction." By Mr. Henry Aitken.

"Geology, Mining, and Economic Uses of Fuller's Earth." By Mr. A. C. G. Cameron.

"The Ghorband Lead-mines, Afghanistan." By Mr. A. L. Collins.

"The Probable Range of the Coal-measures in Southern England." By Prof. W. Boyd Dawkins.

"The Coal-fields of Labuan, Borneo." By Mr. R. Fisher.

"The Gold-deposits of Siberia." By Mr. A. Foniakoff.

"Geology of the Southern Transvaal." By Mr. Walcot Gibson.

"The Mineral Development of Nova Scotia." By Mr. E. Gilpin, Jun.

"Note on the Antimony Deposit of El Altar, Sonora, Mexico." By Mr. Edward Halse.

"Note on the Occurrence of Mercury at Quindiú, Tolima, U.S. Colombia. By Mr. Edward Halse.

"The Structure of the Forest of Wyre Coal-field." By Mr. Daniel Jones.

"A Short Description of the Hæmatite Deposit Worked by the Salter, Eskett, and Winder Gill Mines, and the Method of Working it." By Mr. J. D. Kendall.

"Singareni Coal-field, Hyderabad, India." By Mr. J. P. Kirkup.

"Gold and other Mineral Resources of Western Australia." By Mr. R. H Lapage.
"Geology of the West Yorkshire Coal-field." By Prof. A. Lupton.
"The Mid-Lothian Coal-basin." By Mr. R. Martin.
"The Coal-fields of Sonora, Mexico." By Mr. James Overend.
"Minerals and Mining in Tasmania." By Mr. A. P. Wilson.

Mining engineering has been dealt with in the following papers :—

"History and Description of the Greenside Silver-lead Mine, Patterdale." By Mr. W. H. Borlase.
"Notes on Work Done by the Stanley Heading-machines at Hamilton Palace Colliery." By Mr. J. S. Dixon.
"Limestone Mining in Scotland." By Mr. John Morison.
"Stoppings on Underground Roads." By Mr. E. B. Wain.
"The Jeffrey Electric Coal-cutting Machine." By Mr. R. S. Williamson.
"Notes on Coal-getting by Machinery." By Mr. T. H. Wordsworth.

The following papers have been contributed relative to mechanical engineering :—

"Safety-catches in Connexion with Mining Cages and Hoists." By Mr. Andrew Caseley.
"The Use of Expansion-gear as Applied to Colliery Engines." By Mr. M. Deacon.
"The Victoria Friction-clutch." By Mr. L. Dobinson.
"The Transmission of Power by Compressed Air." By Prof. Goodman.
'The Melling Steam Reversing-gear." By Mr. John Heath.
"Notes on Mr. R. H. Wynne's Paper on 'The Application of Mechanical Arrangements in Underground Operations.'" By Mr. T. Vaughan Hughes.
"Corliss-engined Fan at Seghill Colliery." By Mr. C. C. Leach.
"The Bearing-surface of Pump-valves." Report of the Committee of the Mining Institute of Scotland.
"A New Pit Pump." By Mr. R. Thomson.
"The Application of Mechanical Arrangements in Underground Operations." By Mr. R. H. Wynne.

The following papers have been communicated on the subjects of mine ventilation, safety-lamps, etc. :—

"The Veitch-Wilson Improved Lamp-pricker." *Anon.*
"Safety-lamps with Standard Flames for Keen and Accurate Gas-testing." By Mr. J. Ashworth.
"The Hydrogen-oil Gas-testing Safety-lamp." By Prof. F. Clowes.
"The Proportion of Carbon Dioxide (Choke-damp) in Air which is Extinctive to Flame." By Prof. F. Clowes.
"The Sussmann Electric Lamp." By Mr. V. C. Doubleday.
"A Contribution to the History of Fire-damp." By Mr. H. G. Graves.
"The Friction of, or Resistance to, Air-currents in Mines." By Mr. Daniel Murgue.
"Result of an Experimental Research into Choke-damp Poisoning, with Special Reference to Oxygen as a Restorative." By Dr. W. Ernest Thomson.

The question of coal-dust has been discussed in the following papers:—

"A Contribution to our Knowledge of Coal-dust. Part II." By Dr. P. Phillips Bedson.

"A Contribution to our Knowledge of Coal-dust. Part III." By Dr. P. Phillips Bedson and Mr. W. McConnell, Jun.

"The Combustion of Oxygen and Coal-dust in Mines." By Mr. W. C. Blackett.

"Coal-dust in Mines and its Relation to Explosions." By Mr. C. Dunbar.

The use of explosives has been the subject of the following papers:—

"Notes on Blasting in Coal-mines." By Mr. H. Bigg-Wither.

"A New Method of Tamping and Ramming Boreholes." By Mr. H. Johnson.

"Mining Explosives: Their Definition as Authorized under the Explosives Act, 1875." By Mr. A. C. Kayll.

"Miss-fires." By Mr. J. D. Kendall.

The preparation of minerals has been considered in the following papers:—

"The Baum Coal-washing Machinery." By Mr. Fritz Baum.

"The Choice of Coarse and Fine-crushing Machinery and Processes of Ore Treatment." By Mr. A. G. Charleton.

"Coal-washing at North Motherwell Colliery." By Mr. John Hogg.

"The Lührig System of Coal-washing." By Mr. G. Blake Walker.

Electrical subjects have been considered in the following:—

"The Best Means of Conveying Electric Energy in a Fiery Mine." By Mr. A. W. Bennett.

"The Sussmann Electric Lamp." By Mr. V. C. Doubleday.

"The Electric-power Plant at Dumbreck Colliery, Kilsyth." By Mr. J. T Forgie.

"The Jeffrey Electric Coal-cutting Machine." By Mr. R. S. Williamson.

The subject of "Rating of Mines" has been treated of in a valuable paper by Mr. E. J. Castle, Q.C., which resulted in a most interesting discussion.

The miscellaneous papers have been:—

"The Manchester Ship Canal." *Anon.*

"The Hilderstone Silver-mine, near Linlithgow." By Mr. Henry Aitken.

"An Open-scale Barometer." By Mr. C. O. Bartrum.

"Barometer, Thermometer, etc., Readings for the Year 1893." By Mr. M. Walton Brown.

"The Oil-shale Industry of France." By Mr. G. Chesneau.

"Spontaneous Combustion in Coal-mines." By Mr. W. S. Gresley.

"On the Report of the Royal Commission on Mining Royalties." By Mr. James Hamilton.

"Notes upon a Practical Method of Ascertaining the Value or Price to be paid for Zinc Mineral." By Mr. H. D. Hoskold.

"Photography in Mines." By Mr. H. W. Hughes.
"Description of the Whitehaven Collieries." By Mr. H. M. James.
"Leicester Sewage Pumping-station at Beaumont Leys." By Mr. E. G. Mawbey.
"Ancient Mining at the Coppice, Sedgley." By Mr. I. Meachem, Jun.
"The Salt Industry of Carrickfergus." By Mr. A. Miscampbell.
"Obituary of Thomas William Embleton." By Mr. T. W. H. Mitchell.
"Historical Sketch of the Whitehaven Collieries." By Mr. R. W. Moore.
"Description of the St. Helen's Colliery, Workington," By Mr. G. Scoular.
"Magnetic Declination and its Variations." By Prof. H. Stroud.

The foregoing lists, comprising 78 papers demonstrate the varied nature of the papers communicated to the members during the year. Many of the papers and the accompanying discussions are of great value.

Prizes have been awarded to the authors of the following papers, which are printed in volumes iv. and v. of the *Transactions*:—

"The Correlation of the Coal-fields of Northern France and Southern England." By Mr. Marcel Bertrand.
"The Choice of Coarse and Fine-crushing Machinery and Processes of Ore Treatment." By Mr. A. G. Charleton.
"The Geology and Coal-deposits of Natal." By Mr. R. A. S. Redmayne.

The "Notes of Papers on the Working of Mines, Metallurgy, etc., from the Transactions of Foreign Societies and Foreign Publications" have been continued, and comprise many subjects of interest to members.

The bulk of the papers has necessitated the *Transactions* being printed in two volumes, an arrangement which will be received with satisfaction by the members.

BOOKS, ETC., ADDED TO THE LIBRARY.

Argall, P., Nickel, The Occurrence, Geological Distribution, and Genesis of its Ore Deposits, 1893.
Barrowman, J., Glossary of Scotch Mining Terms.
British Association for the Advancement of Science. Committee to Organize an Ethnographical Survey of the United Kingdom, January, 1894.
British Association for the Advancement of Science. Reports of Meetings at Leeds, 1890; at Cardiff, 1891; at Edinburgh, 1892; and at Nottingham, 1893.
Cadell, H. M., A Visit to the Coal, Oil, and Anthracite Districts of Pennsylvania, 1891; The Salt Deposits of Stassfurt, 1885; The International System of Water and Sewage Purification, 1891; The Occurrence of Plant Remains in Olivine Basalt in the Bo'ness Coal-field, 1891; Geology as a Branch of Technical Education, 1887; Notes on the Coal Question (with Diagram), 1890.
Campbell, W. G., South African Progress Based on Transvaal Gold, A Sketch of 1893 Results.
Chesterfield and Midland Counties Institution of Engineers, Transactions, vols. iv.-xvii.
Colliery Engineer, vol. xiii., No. 12; vol. xiv., Nos. 1-6.
Collins, J. H., On the Origin and Development of Ore Deposits in the West of England, 1893.

Cory Brothers, British Coal Trade and Freight Circular (Monthly), August, 1893-June, 1894.

Dunn, E. J., Victoria Department of Mines. Report on the Bendigo Gold-field, 1893.

Engineering and Mining Journal, vol. lvi., Nos. 8-27; vol. lvii., Nos. 1-26; vol. lviii., Nos. 1-3.

Emmens, S. H., Report on Mayflower Gold-mine, 1893.

Gilpin, Edwin, Nova Scotia, 1893; Geological Relations of the Principal Nova Scotia Minerals; Minerals of Nova Scotia; Iron Ores of Nova Scotia; Notes on some Explosions in Nova Scotia Coal-mines; The Carboniferous of Cape Breton, with Introductory Remarks, Parts 1, 2, and 3; The Geology of Cape Breton, the Minerals of the Carboniferous; The Geology of Cape Breton, the Lower Silurian; The Devonian of Cape Breton.

Grant, J. S., and Cadell, H. M., The Breadalbane Mines, 1883-84.

Greenwell, G. C., A Practical Treatise on Mine Engineering. Second Edition, 1869.

Head, Jeremiah, Address to the Mechanical Science Section of the British Association, Nottingham, 1893.

Hofman, H. O., Metallurgical Lead Exhibits at the Columbian Exposition.

Hart, Francis, Western Australia in 1893.

Hoskold, H. D., Historical Notes upon Ancient and Modern Surveying Instruments.

Illinois Mining Institute, Journal, vol. ii., Nos. 1-3.

Iron and Steel Institute, Journal, 1875, 1876, 1877; Foreign Reports, 1878-79.

Journal of the General Mining Association of the Province of Quebec, vol. i., 1891-3.

Louis, Henry, A Handbook of Gold Milling, 1894.

MacArthur, J. S., Some Facts and Particulars regarding the MacArthur Process of Gold and Silver Extraction by Means of Cyanide, 1890.

McConnell, W., Jun., Report of an Investigation on the Gases Enclosed in Coal and Coal-dust.

Memoria del Departamenta Nacional [Argentine Republic] de Minas y Geologia Correspondiente al Año de 1891.

Michigan Mining School, Report of the Directors, 1890-92.

Midland Institute of Mining, Civil, and Mechanical Engineers, Transactions, vols. xi. and xii.

Mining Institute of Scotland, Transactions, vols. ii.-xiv.

Mining Society of Nova Scotia, Transactions, vol. ii., Nos. 1-4.

New Zealand, The Mines Statement for 1893, by the Hon. R. J. Seddon, Minister of Mines.

North of England Institute of Mining and Mechanical Engineers, Transactions, vols. i., ii., vii.-xxxviii.

North Staffordshire Institute of Mining and Mechanical Engineers, Transactions, vols. i.-xi.

Poole, H. S., The Pictou Coal-field, A Revision.

Pryde, James, Mathematical Tables, consisting of Logarithms of Numbers from 1 to 108,000, Trigonometrical and other Tables; new edition. W. & R. Chambers, 1893.

Séguela, R., Étude sur Le Graissage des Cylindries et Tiroirs des Machines a Vapeur et sur les Matiéres Lubrificantes.

South Staffordshire and East Worcestershire Institute of Mining Engineers, Transactions, vols. i.-xvi.

South Wales Institute of Engineers, Transactions, vol. xviii.

Stetefeldt, C. A., The Stetefeldt Furnace, 1894.

THE LOCAL INSTITUTES IN ACCOUNT WITH THE FEDERATED INSTITUTION OF MINING ENGINEERS, FOR THE YEAR ENDING JULY 31ST, 1894.

Dr.	No. of Members. Federated.	No. of Members. Non-Federated.	Balance due at the beginning of the year.	Amounts falling due during the Year. Calls made during the year.	Excerpts.	Transactions, Reducing Plates, etc.	Total.
			£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Chesterfield and Midland Counties Institution of Engineers ...	324	...	...	304 6 0	7 7 6	3 0 0	314 13 6
Midland Institute of Mining, Civil, and Mechanical Engineers	220	...	...	205 18 0	11 19 8	4 0 0	221 17 8
Mining Institute of Scotland	371	113	...	371 17 0	21 1 8	3 0 0	395 18 8
North of England Institute of Mining and Mechanical Engineers	841	...	...	788 17 0	59 19 3	26 18 0	875 14 3
North Staffordshire Institute of Mining and Mechanical Engineers	201	10	70 13 6	196 3 0	13 2 7	1 10 0	281 9 1
South Staffordshire and East Worcestershire Institute of Mining Engineers...	98	...	24 7 9	93 2 0	2 4 10	5 0 0	124 14 7
	2,055	123	95 1 3	1,960 3 0	115 15 6	43 8 0	2,214 7 9

Cr.	Amounts paid during the Year. Balance from previous year.	Calls.	Excerpts.	Transactions, Reducing Plates, etc.	Total.	Balance due at July 31st, 1894.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Chesterfield and Midland Counties Institution of Engineers ...	...	302 12 0	7 7 6	2 0 0	311 19 6	2 14 0
Midland Institute of Mining, Civil, and Mechanical Engineers	...	181 13 0	11 19 8	3 0 0	196 12 8	25 5 0
Mining Institute of Scotland	...	371 17 0	21 1 8	2 3 4	395 2 0	0 16 8
North of England Institute of Mining and Mechanical Engineers	...	782 1 0	59 19 3	5 10 0	847 10 3	28 4 0
North Staffordshire Institute of Mining and Mechanical Engineers	70 13 6	175 11 0	11 11 5	0 10 0	258 5 11	23 3 2
South Staffordshire and East Worcestershire Institute of Mining Engineers	24 7 9	71 5 0	...	...	95 12 9	29 1 10
	95 1 3	1,884 19 0	111 19 6	13 3 4	2,105 3 1	109 4 8

Dr. THE TREASURER IN ACCOUNT WITH THE
FOR THE YEAR

				£	s.	d.	£	s.	d.
July 31, 1893—									
To Balance at Bank				125	1	11			
„ „ in Treasurer's hands				20	7	1			
							145	9	0
To Subscriptions for year ending July 31, 1893—									
Federated—									
Chesterfield and Midland Counties Institution of Engineers				28	18	0			
Midland Institute of Mining, Civil, and Mechanical Engineers				18	18	0			
North of England Institute of Mining and Mechanical Engineers				74	0	0			
North Staffordshire Institute of Mining and Mechanical Engineers				82	5	0			
South Staffordshire and East Worcestershire Institute of Mining Engineers				16	0	0			
							220	1	0
To Subscriptions for year ending July 31, 1894—									
Federated—									
Chesterfield and Midland Counties Institution of Engineers	£273	14	0						
Midland Institute of Mining, Civil, and Mechanical Engineers	162	15	0						
Mining Institute of Scotland	315	7	0						
North of England Institute of Mining and Mechanical Engineers	708	1	0						
North Staffordshire Institute of Mining and Mechanical Engineers	150	5	0						
South Staffordshire and East Worcestershire Institute of Mining Engineers	71	5	0						
				1,681	7	0			
Non-Federated—									
Mining Institute of Scotland	£56	10	0						
North Staffordshire Institute of Mining and Mechanical Engineers	5	0	0						
				61	10	0			
							1,742	17	0
To Local Publications and Authors' Copies—									
Chesterfield and Midland Counties Institution of Engineers				7	7	6			
Midland Institute of Mining, Civil, and Mechanical Engineers				11	19	8			
Mining Institute of Scotland				21	1	8			
North of England Institute of Mining and Mechanical Engineers				59	19	3			
North Staffordshire Institute of Mining and Mechanical Engineers				11	11	5			
Carried forward				£111	19	6	2,108	7	0

FEDERATED INSTITUTION OF MINING ENGINEERS. **Cr.**
ENDING JULY 31, 1894.

July 31, 1894.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
By Printing—				
Transactions, Vol. II., printing	......	2 0 0		
„ „ III., printing	......	8 0 0		
„ „ IV., printing	......	76 7 6		
„ „ V., printing	377 11 11			
„ „ V., plates	97 7 6			
		474 19 5		
„ „ VI., printing	381 3 3			
„ „ VI., plates	82 15 3			
		463 18 6		
„ „ VII., printing	243 7 7			
„ „ VII., plates	91 15 2			
		335 2 9		
			1,360 8 2	
Excerpts, Vol. II.	......	3 17 0		
„ „ III.	......	1 6 0		
„ „ IV.	.....	3 10 3		
„ „ V.	......	55 15 5		
„ „ VI.	......	71 19 5		
„ „ VII.	......	44 6 11		
			180 15 0	
Galley Proofs for Revision ...	......	......	8 2 4	
Circulars	......	......	26 1 11	
Proofs of Papers for General Meetings		......	16 17 0	
				1,587 4 5
„ Stationery, etc.	......	......	23 8 9	
„ Postages—Circulars	......	4 0 3		
„ „ Correspondence ...	......	19 10 1		
„ „ Transactions ...	......	197 4 1		
			220 14 5	
„ Addressing Transactions ...	......	......	13 0 0	
„ Insurance of Transactions ...	......	......	1 0 0	
„ Binding, Library		6 14 3		
„ „ Sundries		0 14 6		
„ „ Transactions		63 17 6		
			71 6 3	
„ Reporting		......	10 14 6	
„ Incidental Expenses		7 1 0		
„ Petty Cash		5 9 9		
			12 10 9	
„ Salaries, Wages, etc.		......	389 9 0	
„ Indexing Transactions (2 years)		......	17 13 4	
Carried forward			£759 17 0	1,587 4 5

Dr. THE TREASURER IN ACCOUNT WITH

	£	s.	d.	£	s.	d.
Brought forward	111	19	6	2,108	7	0
South Staffordshire and East Worcestershire Institute of Mining Engineers	3	0	3			
The Federated Institution of Mining Engineers	15	10	1			
				130	9	10
To Sales of Transactions, etc.—						
Chesterfield and Midland Counties Institution of Engineers	1	0	0			
Mining Institute of Scotland	0	3	4			
North Staffordshire Institute of Mining and Mechanical Engineers	1	1	0			
South Staffordshire and East Worcestershire Institute of Mining Engineers	5	7	6			
Members, etc.	102	5	0			
				109	16	10
To Reducing Plates—						
Chesterfield and Midland Counties Institution of Engineers	1	0	0			
Midland Institute of Mining, Civil, and Mechanical Engineers	3	0	0			
Mining Institute of Scotland	2	0	0			
North of England Institute of Mining and Mechanical Engineers	5	10	0			
North Staffordshire Institute of Mining and Mechanical Engineers	0	10	0			
				12	0	0
To Advertizements				454	4	2
				£2,814	17	10

THE FEDERATED INSTITUTION OF MINING ENGINEERS.—*Continued.* Cr.

	£ s. d.	£ s. d.	£ s. d.
Brought forward	......	759 17 0	1,587 4 5
By Travelling Expenses—Secretary	41 13 5		
" " " Treasurer	11 10 0		
		53 3 5	
			813 0 5
" Advertizements—Commission	104 9 6		
" " Printing	0 9 6		
" " Stamps	0 10 0		
		105 9 0	
" Prizes, Vols. III. IV. and V.		30 0 0	
" Translations of Papers		10 0 0	
" Abstracts of Foreign Papers		76 17 6	
" Barometer Readings		7 8 0	
" Calendar		12 5 0	
			241 19 6
			2,642 4 4
" Balance at Bank		89 6 0	
" " in Treasurer's hands		83 7 6	
			172 13 6
			£2,814 17 10

Liabilities.

	£ s. d.	£ s. d.
Sundry Creditors—		
Printing, etc.	300 0 0	
Postage of Transactions	20 0 0	
Abstracts of Foreign Papers	10 0 0	
Barometer Readings	5 0 0	
Prizes for Papers	15 0 0	
Advertizements Paid in Advance	31 14 2	
		381 14 2
Balance of Assets over Liabilities		707 15 9

I have examined the above Balance Sheet with the books and vouchers relating thereto, and certify that in my opinion it exhibits a correct view of the affairs of the Institution.

JOHN G. BENSON,
Chartered Accountant.

Newcastle-upon-Tyne,
August 23*rd*, 1894.

£1,089 9 11

ENGINEERS.—GENERAL STATEMENT, JULY 31, 1894.

Assets.

	£ s. d.	£ s. d.
Balance at Bank	89 6 0	
„ in Treasurer's hands	83 7 6	
		172 13 6
Subscriptions Unpaid, Year ending July 31, 1893—		
South Staffordshire and East Worcestershire Institute of Mining Engineers...		9 16 0
Subscriptions Unpaid, Year ending July 31, 1894—		
Chesterfield and Midland Counties Institution of Engineers	1 14 0	
Midland Institute of Mining, Civil, and Mechanical Engineers	24 5 0	
North of England Institute of Mining and Mechanical Engineers	6 16 0	
North Staffordshire Institute of Mining and Mechanical Engineers	20 12 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers	12 1 0	
		65 8 0
Excerpts Unpaid—		
North Staffordshire Institute of Mining and Mechanical Engineers	1 11 2	
South Staffordshire and East Worcestershire Institute of Mining Engineers...	2 4 10	
Members, etc....	1 1 4	
		4 17 4
For Reducing Plates—		
South Staffordshire Institute of Mining and Mechanical Engineers		2 0 0
Transactions Sold—		
Chesterfield and Midland Counties Institution of Engineers	1 0 0	
Midland Institute of Mining, Civil, and Mechanical Engineers	1 0 0	
Mining Institute of Scotland	0 16 8	
North of England Institute of Mining and Mechanical Engineers	21 8 0	
North Staffordshire Institute of Mining and Mechanical Engineers	1 0 0	
South Staffordshire and East Worcestershire Institute of Mining Engineers...	3 0 0	
		28 4 8
Advertizements to July 31st, 1894, outstanding		114 14 2
		397 13 8
Transactions in Stock—		
4 Volumes at 12s.	2 8 0	
12 „ 10s.	6 0 0	
6 „ 9s. 9d.	2 18 6	
1 „ 9s.	0 9 0	
9 „ 8s. 3d.	3 14 3	
750 „ 7s.	262 10 0	
14 „ 5s. 3d.	3 13 6	
1,267 „ 4s.	253 8 0	
3,135 Parts at 1s.	156 15 0	
		691 16 3
		£1,089 9 11

ELECTION OF OFFICERS.

The SECRETARY announced the following elections by the Council:—

PRESIDENT.

Mr. W. N. ATKINSON.

VICE-PRESIDENTS.

Mr. J. B. ATKINSON.	Mr. J. DAGLISH.	Mr. J. B. SIMPSON.
Mr. A. BARNES.	Mr. G. B. FORSTER.	Mr. W. SPENCER.
Mr. W. F. CLARK.	Mr. G. A. MITCHELL.	Mr. A. L. STEAVENSON.
Mr. W. COCHRANE.	Mr. J. MITCHELL.	Mr. J. STRICK.
Mr. R. H. COLE.	Mr. J. NEVIN.	

TREASURER.

Mr. R. GUTHRIE.

AUDITOR.

Mr. J. G. BENSON.

The CHAIRMAN said he had very much pleasure in introducing Mr. W. N. Atkinson, who was pretty well known to them all, and in asking him to preside. He could only say that during his term of office he was very much indebted to the assistance he had had from the members of the Council, who had made his path very comfortable. He hoped the same attention would be paid to his successor in the presidential chair.

Mr. W. N. ATKINSON then took the chair, and said he highly appreciated the honour that had been conferred upon him by the Council in electing him President for the coming year. With the assistance and guidance of the Council and of their able Secretary, he trusted that The Federated Institution of Mining Engineers would continue to flourish as it had done in the past. It was a gratification to him that the first meeting over which he was called upon to preside was in a district where he met so many of his old friends. His first duty as President was to propose a vote of thanks to Mr. Sopwith, their late President, for the able manner in which he had discharged his duties during the past year. He was sure they would pass that vote with very great approval.

Mr. THOMAS DOUGLAS (Darlington), in seconding the proposal, said he was glad to know that Mr. Sopwith had been associated with the North of England Institute of Mining and Mechanical Engineers for the past thirty years. It was nearly fifty years since he (the speaker) entered the coal trade, and in 1852 he attended the first meeting of the North of England Institute of Mining and Mechanical Engineers. It was therefore with particular pleasure that, as President of that Institute, he could take the opportunity of giving a hearty welcome to all who had come to Newcastle on this occasion, and he hoped that their visit would be an interesting and instructive one.

The vote of thanks was carried with acclamation.

Mr. A. SOPWITH acknowledged the very cordial way in which the vote of thanks had been adopted. He admitted that it was with some degree of satisfaction he gave up the presidential chair, because after all there was a good deal of work connected with it, especially as they had such an energetic Secretary, who was always in communication on various subjects. He might say, however, that whatever work he had done in connexion with the welfare of The Federated Institution of Mining Engineers had been a work of pleasure. He could only say in conclusion that he appreciated very much their kindness and the cordial manner in which they had approved the vote of thanks.

The SECRETARY read the following paper by Prof. Hull on "The Discovery of a Concealed Ridge of Supposed Cambrian Rocks under the New Red Sandstone of Netherseal, near Ashby-de-la-Zouch, Leicestershire" :—

THE DISCOVERY OF A CONCEALED RIDGE OF SUPPOSED CAMBRIAN ROCKS UNDER THE NEW RED SANDSTONE OF NETHERSEAL, NEAR ASHBY-DE-LA-ZOUCH, LEICESTERSHIRE.*

BY PROF. EDWARD HULL, F.R.S., F.G.S.

It is now generally recognized that the Carboniferous strata of Leicestershire and Warwickshire were deposited in proximity to old land-margins, composed of Cambro-Silurian rocks which jutted out in a north-westerly direction in successive headlands in the Carboniferous sea, and included intervening bays of submerged land. As the land gradually subsided during the Carboniferous period the land-margin gradually receded eastwards, and thus the Upper Carboniferous strata were deposited over wider areas than were the Lower. In this manner we can account for the absence of the Mountain Limestone and other Lower Carboniferous strata, such as the Millstone Grit, in Warwickshire and some parts of Leicestershire and South Staffordshire, while the Coal-measures are more or less fully represented. The old rocks of Charnwood Forest and of Hartshill are visible representatives of this ancient Carboniferous land which was not submerged throughout the Coal period. Similar observations apply to South Staffordshire.

One of the ridges referred to appears to have been struck in borings recently put down by the Netherseal Colliery Company, under the direction of Mr. G. J. Binns, for the purpose of testing the extension of the main coal-seam. The strata passed through were as follows:—

TRIAS—

New Red Sandstone (Bunter). Light reddish-brown pebbly sandstone	262 feet.

* A paper on these interesting borings is given in the *Report of the British Association* for 1893, page 745. On other occasions, the writer has dealt with the subject of the physical geology of the Carboniferous strata of England, particularly in *The Physical History of the British Isles*, pages 79-89, Plates VI. and VII.; "The Triassic and Permian Rocks of the Midland Counties," *Memoirs of the Geological Survey*, chap. xi., page 109. The presence of numerous rock-faults, owing to which the coal-seams are replaced by sandstone, especially in the Coleorton district of Leicestershire, is doubtless due to the proximity of this region to the old land-margin of the Carboniferous period. See "The Geology of the Leicestershire Coal-field," *Memoirs of the Geological Survey*, page 53.

COAL-MEASURES—	
Grey and black shales and sandstones, with coal and ironstone; plants abundant	514 feet.
PROBABLY LOWER CAMBRIAN—	
Reddish, purple, and grey grit, micaceous quartzite (vitreous quartzite in No. 2 borehole) ...	19 „

As the rocks at the bottom of the borehole appeared to be different from those of the Coal-formation, the writer was invited to go down and report upon their geological age. On examining the cores in company with Mr. Binns, the writer came to the conclusion that they belonged to a formation earlier than the Carboniferous; and very probably of Lower Cambrian age. In this view he had the concurrence of Prof. Lapworth, to whom he sent specimens of the cores on returning home.

We arrived at this conclusion (1) from the proximity of the rocks of this period at Hartshill and Charnwood Forest, (2) from the nature of the specimens brought up in the cores themselves, especially the quartzite, and (3) from the entire absence of plant-remains, which were so abundant in the overlying Coal-measures.

If the above view be correct it will be seen that the whole of the Lower Carboniferous series (including the Mountain Limestone, Yoredale beds and Millstone Grit, together with the lower beds of the Coal-measures themselves) are here absent. There is represented to us, in effect, a vast *hiatus* or gap in the geological sequence of the strata; for we pass at once from the Lower Cambrian to the Upper Carboniferous; the beds of the Ordovician, Upper Silurian, Devonian and Lower Carboniferous being altogether unrepresented.

Mr. W. SPENCER (Leicester) had observed several cases, in Leicestershire, where the New Red Sandstone was reposing on granite or syenite, all the other formations being entirely absent. The discovery at Netherseal colliery was of great interest, as it would form a guide to the occurrence of the older measures.

The PRESIDENT remarked that 19 feet was a short distance on which to base any positive conclusions as to existence of the older rocks.

Mr. A. SOPWITH said it would be interesting to know with certainty the nature of the rocks lying below the Coal-measures, because the whole of the South Staffordshire Coal-measures (which were practically in the same district) rested directly upon Silurian rocks.

Mr. W. B. Scott (H.M. Inspector of Mines) said that he had recently examined the southern outcrop of the Worcestershire coal-field, and found quartzites similar to those referred by Prof. Hull to the Cambrian formation. If the base of the edge of the coal-field was formed of quartzites and other Cambrian rocks—as it was proved to be by the quarried rocks on the surface, without the necessity of a borehole—it was an easy matter to argue that the whole floor of the basin on which the coal-field had been deposited was formed of quartzite and Cambrian rocks. He thought that the borehole described should be considered as revealing the truth, and that correct conclusions had been drawn by Profs. Hull and Lapworth.

The President then proposed a vote of thanks to Prof. Hull for the paper.

Mr. T. Douglas seconded the resolution, which was cordially adopted.

The following paper by Mr. C. A. Stetefeldt on "The Stetefeldt Furnace" was taken as read:—

THE STETEFELDT FURNACE.*

BY C. A. STETEFELDT, OAKLAND, CAL.

In the year 1867, the author erected a small experimental Gerstenhöfer furnace at the Manhattan mill, Austin, Nevada, for the chloridizing-roasting of silver-ores. The experiment was not a success. Although the ore was fairly well roasted, two difficulties presented themselves: (1) The roasted ore, owing to its sticky nature, accumulated on the lower rows of shelves above the fireplace, and had to be frequently removed. (2) A large percentage of unroasted dust escaped through the flue, leaving the furnace near the top. Further experiments were abandoned at the Manhattan mill, because the superintendent, a native of Ireland, considered the process a "chemical monstrosity."

In the following year, the first Stetefeldt furnace proper was put up at the Murphy mill, Ophir Cañon, Nevada. It consisted of a plain shaft, 4 feet square at the bottom, 3 feet square at the top, and 25 feet high, with one fireplace near the bottom and another fireplace—the so-called auxiliary fireplace—attached to the flue which connected the upper part of the shaft with the dust-chambers. The feeder, which closed the top of the shaft, consisted of a cast-iron plate with a number of narrow slits over which fluted rollers were revolving, similar to the feeder used for the Gerstenhœfer furnace. After starting the furnace, it soon became evident that roasting in the shaft was a complete failure. The dust, however, escaping through the flue, passing the flame of the auxiliary fireplace, and collecting in the dust-chambers, proved to be highly chloridized. This immediately led to the conclusion that a feeder of entirely different construction should be provided. Allowing the ore dropping down the shaft to collect on a piece of sheet-iron, it was observed that by far the larger portion was not scattered, but landed in the form of lumps or sheets; hence the heat could not sufficiently penetrate these dense ore-masses to effect their roasting. After a feeder had been constructed on the same principle as the one now in use, (the feeder shown in Figs. 1 and 2, is only more perfect in its mechanical details) the ore in the shaft roasted remarkably well, and the success of the Stetefeldt furnace became an accomplished fact. The furnace at the Murphy mill had been put up only as an experiment

* Principally compiled from various papers communicated by the author to the American Institute of Mining Engineers.

outside of the mill, and without provision to run in connexion with the latter. The ore was hoisted in buckets to the feeder, and an Indian squaw who faithfully turned a crank served as motive power for the latter. The construction of a new furnace had to be abandoned on account of the sudden failure of the Murphy mine to supply sufficient ore for running the mill.

In the year 1869, the author erected the first Stetefeldt furnace for actual mill-work at Reno, Nevada, at a mill belonging to the Nevada Land and Mining Company, an English corporation. The great success

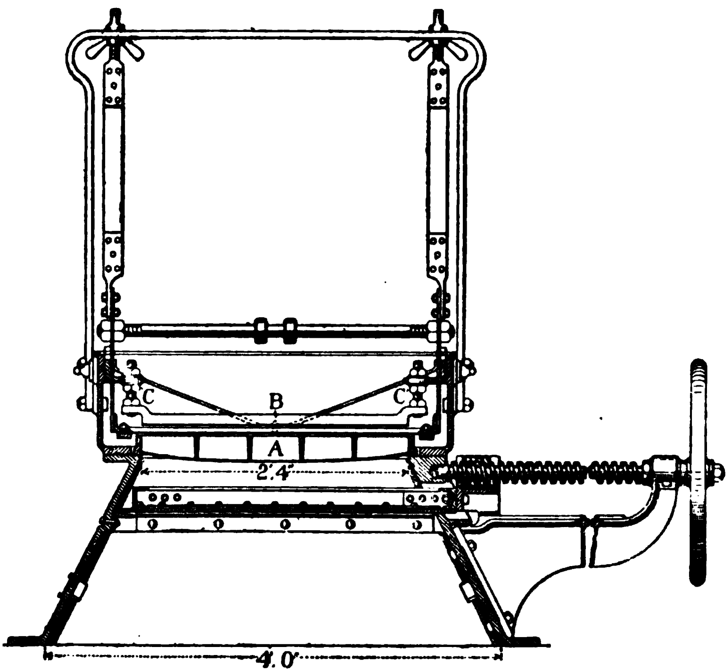


Fig. 1.—Longitudinal Section.

of the furnace at Reno induced the Manhattan company at Austin, Nevada, to acquire the exclusive right to use the Stetefeldt furnace in the Reese River district, by paying £5,000 and a royalty of 8s. per ton of ore, and the author built a furnace of improved construction at the Manhattan mill in 1870. Furnaces were now put up in quick succession in the principal mining-camps of Nevada, and subsequently in Utah, Montana, and Colorado.

1.—*The Stetefeldt Feeder.*—The Stetefeldt feeder, shown in Figs. 1 and 2, consists of a cast-iron grate A, covered by a punched steel-

sheet with holes of $\frac{1}{8}$ inch or less in diameter, through the openings of which the ore-pulp, mixed with salt, is fed by the oscillating motion of the wrought-iron rocker B. A coarse wire-screen, No. 4, is stretched over the frame of the rocker. The necessary friction is created by the stationary blades C. The distance between the punched-screen and the wire-screen, and between the latter and the lower edges of the blades, can be regulated, as also the number of strokes the rocker makes per minute, whereby it becomes possible to feed into the furnace, with the same machine, almost any desired quantity of ore. The coarser and warmer

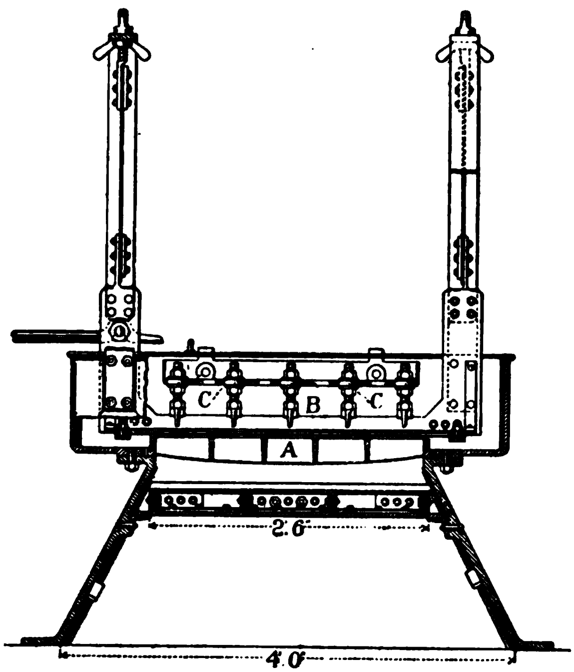


Fig. 2.—Transverse Section.

the pulp, the easier works the feeder. A damper, moved by a screw, is inserted below the grate A, whenever it becomes necessary to exchange worn-out screens. This is also done when the feeding of ore is stopped for any length of time.

The rocker of the Stetefeldt feeder, with coarse wire-screen, which was formerly supported by friction-rollers, is now suspended by adjustable, flexible steel-bands, as shown in Figs. 1 and 2. A change in the frame of the feeder was made many years ago. Originally it was in the form of a water-jacket. This caused a serious accident at Mineral Hill,

Nevada. The wise chief engineer of the mill had provided the influx as well as the discharge water-pipe of the jacket with cocks. Some thoughtless fellow had shut both cocks, and when the furnace was fired up, after a clean-up of the mill, the fireman noticed some steam issuing from the water-jacket. As he stepped near, an explosion took place, and, blinded by dust, the man staggered forward and dropped into the hot shaft. Although taken out alive, he died shortly afterwards. From that time the water-jacket was discarded, and it proved to have been superfluous.

It is hardly necessary to say that the feeder is continuously supplied with the mixture of ore and salt by a cup-elevator. The latter is fed from an ore-bin and from a salt-bin, both being provided with automatic feeders.

2.—*Construction of the Stetefeldt Furnace.*—The furnace at Reno had been provided with fireplaces for burning wood. In the Austin furnace, the author made a material change in constructing the two fireplaces for the shaft, and the auxiliary fireplace for the flue, in the shape of gas-generators for burning charcoal, or a mixture of charcoal and wood. In consequence of the excellent results obtained with this system at Austin, furnaces of the same construction were put up at Mineral Hill, Belmont, and Secret Cañon, all in Nevada. The author, however, soon discovered that such complicated apparatus was not safe in the hands of the average "muscular amalgamator," and returned to building furnaces with ordinary fireplaces for wood. At Belmont, an explosion destroyed the arches of the dust-chambers, the foreman of the mill having neglected to light the gas after starting the generators. At Secret Cañon, a quicksilver-bottle, filled with water, and fastened to a hemp-rope, was used as a counter-weight for the cover of one of the generators. In lifting the cover the rope broke, and the quicksilver-bottle dropped into the generator-shaft. The fireman did not consider that this might have serious consequences. After a while a terrific explosion shattered the walls of the generator, but fortunately did no other damage.

It is evident that in a furnace receiving fresh supplies of ore continuously, and performing the roasting in a few seconds, a uniform temperature must lead to better results, economically as well as from a metallurgical standpoint.

For this reason the author has recently returned with great success to the problem of firing the furnace by gas, made in a Taylor gas-producer from mineral coal. In 1890, he reconstructed the furnace at the Marsac mill, Park City, Utah, for gas-fires, and made the same change on the two furnaces of the Ontario mill, in 1893.

Figs. 3 to 10, in which the principal dimensions are specifically given, represent the latest design of the Stetefeldt furnace, as built at the Holden mill, Aspen, Colorado, in 1891.*

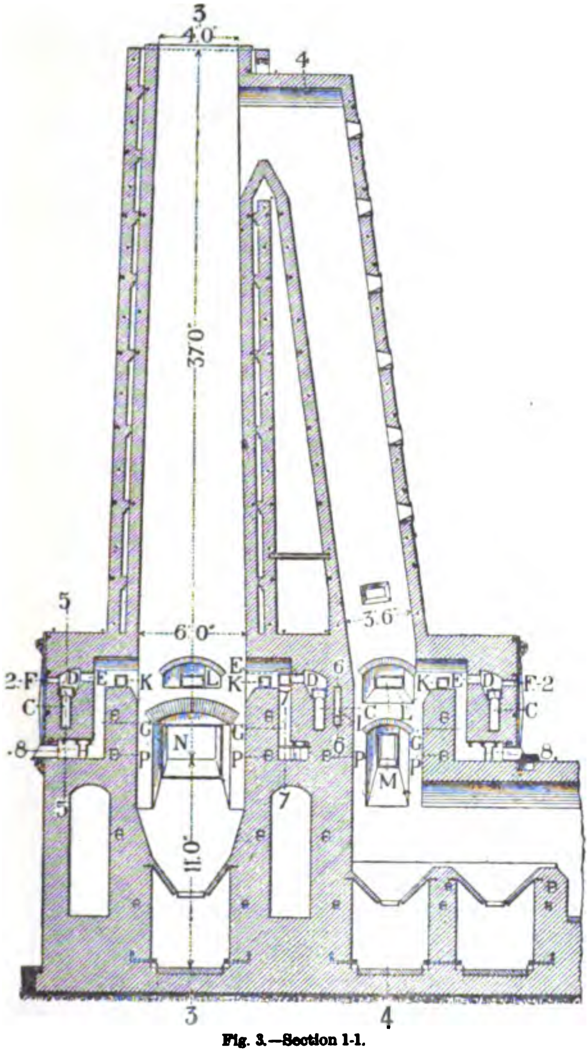


Fig. 3.—Section 1-1.

The spiral-weld steel-tube A, provided with expansion-joints B, supplies gas from a Taylor gas-producer to the cast-iron burners C, which have openings with covers in front for cleaning out soot and tar. The

* Drawings of the Stetefeldt furnace of older construction can be found in any of the recent text-books on metallurgy.

gas escapes from the burners through square holes on the top. These can be more or less closed by cast-iron slides (not shown in the drawings), the handles of which move through the covers of the frames D, thus regulating the supply of gas. The latter escapes into the combustion-chambers through the openings E. Should soot accumulate here it can be removed through

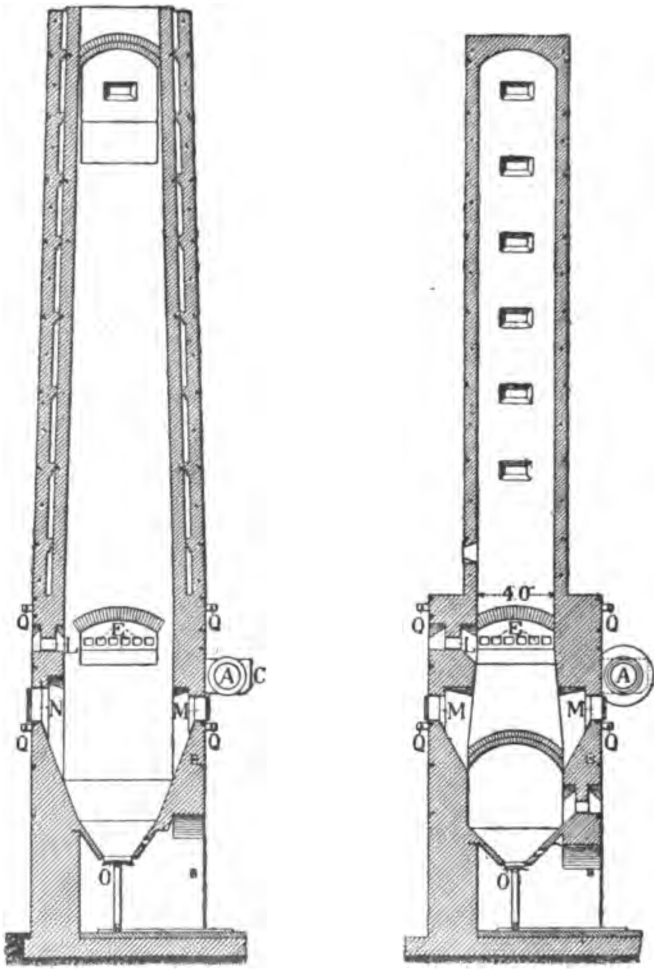


Fig. 4.—Section 3-3. Fig. 5.—Section 4-4.

the pipes F, ordinarily closed by iron plugs. Air for combustion ascends through the channels G, and the air-supply is regulated by sheet-iron slides at the air-doors H. The air-channel I, in the wall between shaft and flue, is provided to prevent over-heating of the gas-burner. The fire-bridges can be cleaned through the openings K, and also through the doors L.

Air can be supplied below the fire-bridges through the doors M, and the big door N, on the shaft is used for cleaning the hopper. For discharging the roasted ore from the hoppers into cars beneath, the swinging dampers

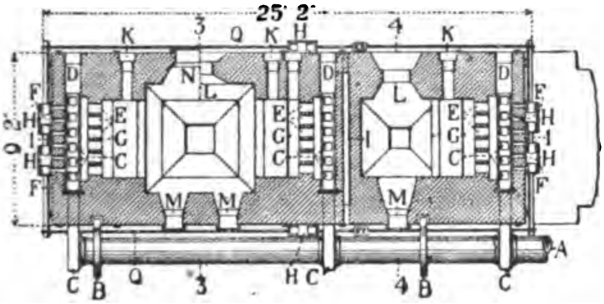


Fig. 6.—Section 2-2.

O, are pushed back by handles running in guides, which are not shown in the drawings. It will be noticed that many rails (30 pounds per yard) are inserted in the walls of the furnace. Anchor-holes P, running through hot walls, are made two courses of bricks high, 3 inches wide inside and wider at the faces of the walls, so that they are not closed by the perpendicular buck-straps. The long walls of the lower part of the furnace are anchored outside by the rods Q. All walls are braced by wrought-iron buck-straps between anchor-rods. Where ordinary bricks of good quality can be obtained, a lining of fire-brick is only necessary in the lower part of the shaft and flue, commencing about 4 feet above the fire-bridges in the shaft and at the fire-place in the flue. Other details of the furnace do not require description.

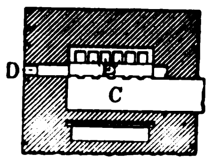


Fig. 7.—Section 5-5.

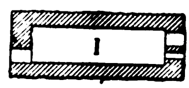


Fig. 8.—Section 6-6.

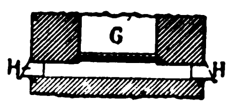


Fig. 9.—Section 7-7

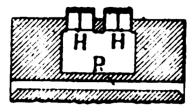


Fig 10.—Section 8-8.

The first furnaces built, roasting from 20 to 25 tons of ore per day, had no hopper-discharges, the charge being drawn with a hoe from the bottom of the shaft through a door. This proved to be inconvenient for a larger output, especially where the ore had to be banked on the cooling-floor in order to improve the chlorination of the silver. The height of the furnace has been increased from 30 to 48 feet, greater height being necessary for furnaces of large capacity roasting ores rich in sulphides, and partly on account of the arrangement of hopper-discharges.

3.—*Dust-chambers.*—The construction of dust-chambers, shown in Figs. 11-15, has not been changed recently. The chambers for large furnaces are generally built 4 feet wide, 10 feet deep, and 16 feet

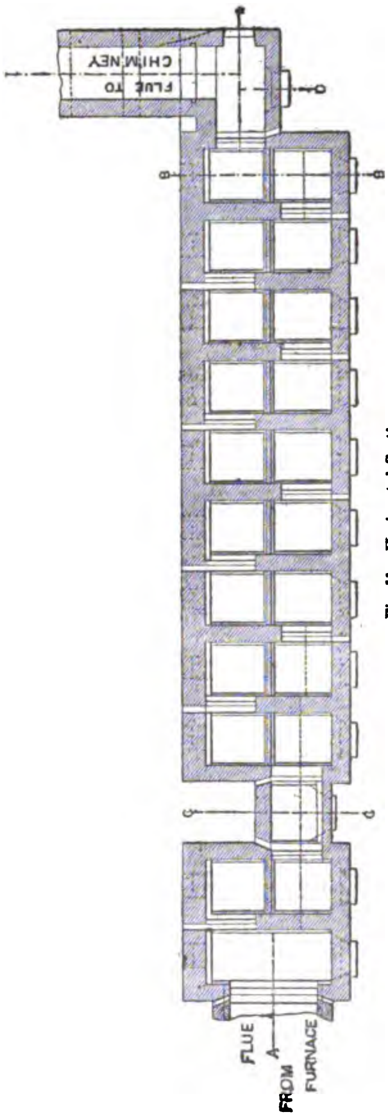


Fig. 11.—Horizontal Section.

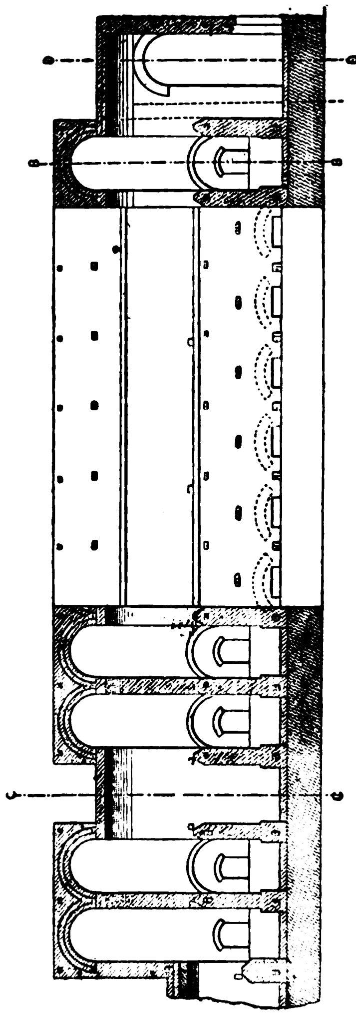


Fig. 12.—Section A-A.

high (inside dimensions). Each chamber is divided by an apron, so that the dust-laden gases have to travel up and down and sideways, thus constantly changing their direction, and impinging against the walls,

whereby a quick settling of the dust is effected. Dust from ore which has been well chloridized, by passing through the flame of the auxiliary fireplace, settles much better and quicker than raw or imperfectly roasted dust, because it is more or less sticky and adheres to a wall when carried against it by the draught. In an experiment at the Ontario mill, it was found that of the dust, escaping from the shaft of a Stetefeldt furnace, 82 per cent. settled in the flue below the auxiliary fireplace, 16·5 per cent. in the first six, and 1·5 per cent. in the last six dust-chambers. The first two dust-chambers next to the flue below the auxiliary fireplace get very hot, and for this reason they are separated from the other chambers whereby a better anchoring is secured. The floor of the dust-chambers is best made of cement-concrete, which lasts much better than a brick-floor. Cement-concrete is also used for the cooling-floor, which should be smooth for moving the ore-cars. The ground-plan of a large Stetefeldt

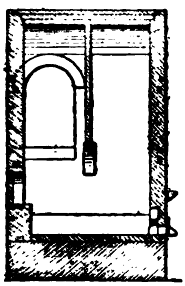


Fig. 13. Section B-B.

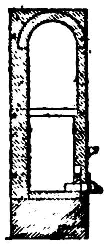


Fig. 14. Section C-C.

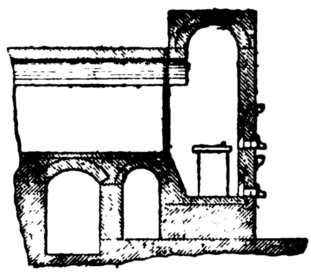


Fig. 15.—Section D-D.

furnace covers an area of 9 feet 2 inches by 25 feet 2 inches, and the dust-chambers, including their connexions with the furnace and the flue to the chimney, take up a space of 12 feet by 76 feet.

4.—*Chimney.*—A chimney for a large Stetefeldt furnace is built with a draught-section of 5 feet square, and the top of the chimney should be 100 feet above the top of the Stetefeldt furnace-shaft. Since silver-mills are generally located on the slope of a hill, it is advisable to run a flue, 4 feet wide and 6 feet high, from the last dust-chamber some distance up the hill, and build the chimney there. This flue, at the same time, serves as an additional dust-chamber and saves a considerable quantity of dust. It is always well to have a superabundance of draught, which can be easily regulated by a damper at the exit of the last dust-chamber.

5.—*Cost of Construction.*—It would be of little value to give the cost of erecting Stetefeldt furnaces in pounds and shillings. The table below contains a full statement of all materials necessary for building a Stete-

feldt furnace of the largest size, including dust-chambers, chimney, and pulp retaining-wall on the cooling-floor, from which estimates of cost can be made for a given locality. The construction of furnaces of smaller size is nearly as expensive, *i.e.*, they require about the same amount of castings, and the rest of the plant is not reduced in proportion to the capacity.

A. Stone and Bricks.—*Stone* for lower part of furnace and dust-chambers above foundation below level of cooling-floor, 3,000 cubic feet. *Common Bricks.*—From 250,000 to 300,000, according to length of flue between dust-chambers and chimney. *Fire-bricks.*—From 4,000 to 10,000, dependent on the quality of common bricks.

In calculating labour on brickwork, the following will serve as a basis:—One mason, with helper, will lay from 750 to 800 bricks per shift of 10 hours.

B. Castings and Ironwork:—

	Pounds.
Plain castings ...	12,250
Castings with finishing	3,600
Forged work ...	1,580
Sheet-iron work	760
Buck-straps ...	9,400
Plain wrought-iron bars	900
Bolts ...	4,300
Rails ...	9,600
Ore-cars (3) ...	1,250
Feeder ...	3,000
Punched screens (24) ...	300
No. 4 wire-screen (100 feet) ...	350
Total weight ...	47,290

This includes tools, and plates and anchor-bolts for the pulp retaining-wall on the cooling-floor. In addition to this, if the furnace is to be fired by gas, there will be the cost of a Taylor gas-producer of 6 feet in diameter, and of the necessary tubes for conducting the gas to the furnace.

6.—*Application of the Stetefeldt Furnace.*—The Stetefeldt furnace was especially invented and designed for the chloridizing-roasting of silver-ores, necessary for subsequent beneficiation by amalgamation or lixiviation; and in this field it has been, and is now, largely, successfully and exclusively used. Whether it can roast to advantage pyritic ores preparatory to smelting in reverberatory or blast-furnaces has never been proved or disproved, the smelters persistently refusing to try the experiment on account of the expense, because such a furnace must be built on a large scale. That silver-ores carrying a very large percentage of pyritic

mineral can be well chloridized in a Stetefeldt furnace has never been claimed, because this cannot be done directly in a reverberatory-furnace either. In the latter furnace, an oxidizing-roasting of ores high in sulphur always precedes the admixture of salt. Hence, if such ores are to be chloridized in a Stetefeldt furnace, they should be first partly desulphurized either by heap-roasting or by roasting in a Gerstenhöfer or Hasenclever furnace. The ore from the Sombrerete mine, Mexico, was only successfully chloridized in a Stetefeldt furnace, after it had been subjected to a somewhat crude and hasty heap-roasting.

There has been, however, a good deal of misunderstanding about this point. Some metallurgical writers have said that the Stetefeldt furnace could be used only for roasting oxidized or so-called "chloride ores," because they happened to see a furnace in operation on such material; others have limited its use to ores containing below 8 per cent. of sulphur, misled by an equally limited experience. As a rule, no sulphur determinations have been made in mills where the Stetefeldt furnace roasted ores of more or less base character; in two instances, however, this was done. The Ontario base ore from the 500 feet level contained 7·68 per cent. of sulphur before roasting, and the roasted ore from the shaft contained 0·18 per cent., and that from the flue 0·06 per cent. of sulphur, *i.e.*, in undecomposed sulphides. The mineralogical composition of the Ontario ore was as follows:—

15·00	per cent. of	zinc-blende, containing		6·0	per cent. of the silver in the ore.
7·60	„	galena,	„	5·8	
4·55	„	fahlore,	„	88·2	
3·50	„	iron pyrites,	„	Trace.	
69·35	„	gangue, composed of quartz and clay.			

In an average pulp sample, from 30,000 tons of ore at the Aspen mill, 8·1 per cent. of sulphur were found before, and 0·2 per cent. after chloridizing-roasting. A complete analysis of the ore gave the following result:—SiO_2, 21·7; $BaSO_4$, 20·9; CaO, 11·0; MgO, 4·2; Fe, 10·0; Zn, 2·9; Pb, 2·3; Cu, 0·16; S, 8·1 per cent.; silver, 24 ounces per ton.

7.—*Capacity of the Stetefeldt Furnace.*—The capacity of the Stetefeldt furnace, like that of any roasting-furnace, is principally a function of the percentage of sulphur in the ore; with good draught, however, it appears to be almost unlimited. The older Stetefeldt furnaces had very light work to do, the capacities of the stamp-batteries for crushing the ore rarely exceeding 30 tons per day. In recent times much larger quantities of ore have been roasted per day. At the Ontario mill, the regular output of one furnace is 40 tons of ore per day; experimentally, however, one

furnace has roasted at the rate of 126 tons per day, using a No. 6 screen on the battery. The Marsac furnace roasts 70 tons per day, and the furnace in the Aspen mill handles easily 90 tons per day, the ore carrying 8 per cent., and more, of sulphur.

8.—*Fine Crushing.*—Those who have had no experience with the Stetefeldt furnace are still under the impression that for chloridizing-roasting the ore must be pulverized exceedingly fine, finer than for any other furnace. This is absolutely erroneous. If silver-ores are to be roasted in a Stetefeldt furnace to prepare them for extraction by amalgamation or lixiviation, they do not require finer crushing than for roasting in Brückner, Howell, or reverberatory-furnaces.

In all cases alike the required fineness of crushing (the author refers here to crushing by stamps exclusively) depends on the character of the ore, *i.e.*, whether the silver-bearing minerals are finely impregnated in the gangue or not. In amalgamation the coarseness of crushing is limited by the capacity of the settlers to work off coarse sand; and this limit is a 26 mesh wire-screen. For lixiviation there is no limit of coarseness, and the most advantageous size of the screen is entirely dependent on the character of the ore. The Ontario ore is very interesting in this respect. Its principal silver-bearing mineral is fahlore (or its products by decomposition), and this never impregnates the quartz, but occurs in little bunches, and frequently on the cleavages of zinc-blende and galena. The latter minerals, if pure, are comparatively low in silver. How little coarse crushing affects the roasting of Ontario ore in the Stetefeldt furnace is shown by the following table:

Mesh of Screen on Battery.	Tons Crushed in 24 Hours.	Rate at which the Stetefeldt Furnace was Fed in 24 Hours.	Salt Used.	Silver Extracted by Russell Process.
	Per Stamp.	Tons.	Per Cent.	Per Cent.
20	2¾	55	12.5	97·0
16	3½	70	12	97·1
10	4½	91	14	93·4
6	6½	126	8	91·9

The lower extraction in the last two experiments may have been due more to overtaxing the capacity of the furnace than to coarse crushing. In the last experiment the lower percentage of salt may have influenced the result. Ontario ore, however, is very exceptional in this respect, and there may not be many ores that could be roasted successfully for lixiviation after crushing through a No. 6 battery-screen.

9.—*The Chlorination of Base Ores on the Cooling-floor.*—It is well known that high chlorinations of silver-ores, containing a large percentage of pyritic minerals, can only be obtained after roasting in a Stetefeldt furnace by leaving the discharged ore for twenty-four hours, or longer, in heaps on the cooling-floor. The same remark applies to the Howell furnace. The incomplete desulphurization and chlorination of a base ore, immediately after discharging from a Stetefeldt furnace, shows itself by the pungent smell of sulphurous and sulphuric acids, and by the presence of a large percentage of magnetic oxide of iron (which can be extracted by a magnet), provided the ore was rich in iron pyrites. After sufficient exposure on the cooling-floor the magnetic oxide disappears either almost entirely or is at least greatly reduced in quantity. Thus, for instance, base ore roasted in the shaft of the Lexington furnace contained 17·5 per cent. of magnetic oxide immediately after discharging, and only 2·3 per cent. after having remained for twelve hours on the cooling-floor. The chlorination of the silver increased during this time from 47·7 to 90·8 per cent.

The question is pertinent: How is the chlorination of the silver effected in heap-roasting? In the first place, the roasted ore piled up on the cooling-floor is by no means inaccessible to the air; on the contrary, it is very porous. While the access of the air is slow, it is practically unlimited if sufficient time be allowed.

The lower oxides (and their salts) of copper, manganese, and iron, easily combine, and their higher oxides easily part with oxygen under certain conditions, thus acting as transferrers of oxygen to other compounds which do not combine with it directly. This is beautifully illustrated by the conversion of sulphurous into sulphuric acid in the Roessler converter. In heap-roasting a similar reaction takes place. Here, the oxygen of the air, at first, slowly attacks the sulphur in the undecomposed sulphides and forms sulphurous acid. The latter, remaining in contact with the higher oxides of copper, manganese, and iron, is converted into sulphuric acid, which decomposes the salt and sets chlorine free. That the lower oxides again combine with oxygen to higher ones is proved by the conversion of the magnetic oxide to ferric oxide inside of the heap after sufficient time has elapsed. As, in the Roessler converter, the reducing and oxidizing reactions, producing sulphuric acid, go on simultaneously; but they cease when all the undecomposed sulphides have disappeared, or the temperature has become too low. If the access of air were excluded none of these reactions could take place in heap-roasting. With the reactions effecting

the chlorination of the silver we need not concern ourselves here. The author has observed that, other conditions being the same, silver-ores containing a fair percentage of copper can always be more highly chloridized than those in which copper is absent, or occurs only in very slight quantity. This is due to the fact that copper is the most energetic transferrer of oxygen, of the three metals named, in the formation of sulphuric acid.

10.—*The Constitution of the Ore after Roasting in the Stetefeldt Furnace.*—Samples of roasted Ontario ore (the mineralogical composition of the raw ore has been given above) taken immediately after discharging from the shaft and flue, were subjected to a partial chemical analysis with the following results :—

Roasted ore from the shaft—	Per Cent.
Cupric and cuprous chloride	0·25
Zinc chloride	1·38
Aluminium chloride	1·51
Sodium chloride	3·68
Traces of other chlorides.	
Lead sulphate	3·26
Aluminium sulphate	0·56
Sodium sulphate	4·62
Traces of other sulphates.	
Remainder: Metallic oxides and gangue.	

Roasted ore from the flue—	Per Cent.
Aluminium chloride	1·07
Sodium chloride	3·08
Traces of other chlorides.	
Copper sulphate	0·74
Zinc sulphate	1·48
Aluminium sulphate	2·88
Lead sulphate	5·18
Sodium sulphate	10·01
Traces of other sulphates.	
Remainder: Metallic oxides and gangue.	

The separation of the soluble metallic chlorides and sulphates was effected by alcohol, in which the chlorides are soluble, and the sulphates are not. After treatment with alcohol, the soluble sulphates were extracted by water.

It appears from these analyses that copper and zinc are only present in the shaft as chlorides, and in the flue only as sulphates. The sulphates of lead and aluminium predominate in the flue, and aluminium chloride predominates in the shaft. Sodium sulphate also predominates in the

flue. Whether this holds good generally with ores roasted chloridizing in the Stetefeldt furnace the author does not know, such investigations not having been carried out elsewhere.

11.—*The Volatilization of Silver by Chloridizing-roasting in the Stetefeldt Furnace.*—The evaporation or volatilization of all substances is governed by the same general laws. The effective elements are: Time, temperature, surface exposed, character of the atmosphere in which evaporation or volatilization takes place, density or pressure of the latter, and its motion or exchange in relation to the substance evaporated or volatilized. Thus, for instance, more silver is volatilized in roasting a small ore-sample in a muffle than in actual reverberatory-furnace work, because more surface is exposed, and the particles have more contact with air in the former case.

If we enquire which of the elements favouring evaporation or volatilization is the most effective—other conditions remaining more or less the same—we must concede that it is time. Now, in the Stetefeldt furnace the roasting, so far as desulphurization is concerned, is instantaneous compared with the same process in any other furnace; hence the claim that the loss of silver by volatilization in the Stetefeldt furnace is a minimum. Unfortunately the actual and direct proof that this view is correct under all circumstances is lacking. The ordinary metallurgical statistics of silver-mills are perfectly worthless for such delicate investigations. In the first place, in mills reducing ores from mines belonging to the same company, the weight of the raw ore is only taken approximately and without making moisture-tests. In the second place, the so-called commercial assays for silver, on which all mill-statistics are based, is from 5 to 15 per cent. short of the actual value, whence originate the so-called "plus clean-ups" of silver.

To ascertain the loss of silver by experiments on a large scale in a direct way, namely, by weighing and sampling the ingoing raw ore and the outgoing roasted ore is attended with so much inconvenience and expense that the writer has never been able to find parties in charge of any mill employing Stetefeldt furnaces willing to undertake it. Hence, he had to get at the question by an indirect method. If a sulphide ore be subjected to an oxidizing-roasting the outgoing elements are generally of greater weight than the ingoing ones, and the result is a loss in weight. The same is the case in chloridizing-roasting, provided we compare the weight of the raw ore without salt with the weight of the roasted ore after leaching out the soluble salts. Under the circumstances it follows

that the assay-value of the roasted ore must be greater than that of the raw ore, in proportion to the loss in weight which the latter has suffered, provided no silver has been volatilized. If, however, the roasted ore should fail to come up to the required value no other inference can be drawn but this, that silver has been lost in roasting.

In 1880, the writer carried out at the Ontario mill, under circumstances that are not likely to occur again, a series of comparative experiments on the Stetefeldt and Howell furnaces. In one of these experiments the ore treated by both furnaces was exactly the same. It came from the same stamp-battery, and after being elevated to a hopper was distributed from the spout of a conveyor-trough, one-half going to the Stetefeldt and the other half to the Howell furnace. The latter had been provided with a system of dust-chambers as complete and well-constructed as that attached to the Stetefeldt furnace. The roasted ore was discharged into cars and carefully sampled. At the end of the experiment both systems of dust-chambers were cleaned out. The average results, after a run of six days, were as follows :—

	Ounces of Silver per Ton.
Value of raw ore	106·0
Value of roasted ore, after leaching out soluble salts,	
from Stetefeldt furnace	112·5
from Howell furnace	98·1

The difference being 14·4 ounces of silver per ton, or 13·5 per cent. of the silver in the ore. This difference represents the loss of silver by volatilization in the Howell furnace above that in the Stetefeldt furnace. That the latter must be very small is evident from the much higher value of the roasted ore compared with the raw ore. The increase in value corresponded very nearly with the loss in weight, as ascertained by muffle roasting-tests, which the raw ore suffered during roasting. In these experiments 28 tons of ore were roasted per day, and divided between the two furnaces, running them only at half capacity. In regard to the Howell furnace this had the effect of keeping the ore much longer in the cylinder than if the latter had received the full charge of 28 tons.

Subsequently the Howell furnace was kept running for ten days at full capacity, receiving the ore from 20 stamps, and the Stetefeldt furnace was supplied from another battery of 20 stamps. The results from the Howell furnace were as follows :—

	Ounces of Silver per Ton.
Value of raw ore	120·6
Value of roasted ore, minus soluble salts	115·5
Difference	5·1

or the roasted ore was 4·2 per cent. lower in value than the raw ore. The results from a forty days' run of the Stetefeldt furnace were as follows :—

	Ounces of Silver per Ton.
Value of raw ore	109·8
Value of roasted ore, minus soluble salts	115·8
Difference	6·0

or the roasted ore was 5·4 per cent. higher in value than the raw ore. This makes a difference of 9·6 per cent. between the two furnaces, and represents the loss of silver in the Howell furnace above that taking place in the Stetefeldt furnace. In comparing the loss of silver resulting in the two experiments, we have again a confirmation of the writer's theory of the influence of time. When the Howell furnace was running at half its capacity, and the ore remained longer in the cylinder, the loss in silver was 3·9 per cent. greater than in the second experiment, when the furnace was running at full capacity. The character of the Ontario ore is such that these losses are by no means astonishing. It contains nearly all the silver as fahlore, rich in antimony and arsenic, and carries a large percentage of zinc-blende. The average values of the tailings resulting from the amalgamation of the roasted ore, and the percentages of soluble salts in the latter, were practically the same for both furnaces, showing that the roasting was equally well done in each instance.

12.—*The Volatilization of Gold by Chloridizing-roasting in a Stetefeldt Furnace.*—It is a well-known fact that the loss of gold in chloridizing-roasting, using a reverberatory or Brückner furnace, may be enormous, and that it is principally a function of time. Messrs. Kuestel and Aaron record losses of from 20 to 50 per cent. The author, by chloridizing-roasting of gold-ores in a reverberatory-furnace in Mexico, suffered losses from 53 to 86 per cent. The ore contained 0·2 to 0·9 ounce of gold per ton. Its gangue was magnetite, with a small amount of quartz and garnet; the gold-bearing sulphides were copper pyrites (from 3·5 to 7 per cent.) and iron pyrites (from 3 to 22 per cent.). That not any more gold than silver is lost by chloridizing-roasting in a Stetefeldt furnace, is shown by the following statement.

At the Lexington mill, Butte, Montana, a silver-ore that contains a considerable amount of gold is subjected to a chloridizing-roasting in the Stetefeldt furnace. The ore is composed of silver-bearing iron pyrites, zinc-blende, galena, and some native silver, with quartz-gangue, sometimes replaced by silicate of manganese. Antimonial and arsenical

silver-minerals are absent, and native gold is not visible. From the character of this ore we can safely infer that it will lose less silver in roasting than Ontario ore, and that in a Stetefeldt furnace this loss must be exceedingly slight. Now if, in the roasted ore, the proportion of silver and gold remains the same as in the raw ore, it follows that also the loss in gold must be very small. The average of about 600 samples, taken at the Lexington mill from October, 1883, to August, 1884, and compiled from the monthly averages of the assayer's report, is as follows:—

	Silver. Ounces per Ton.		Gold. Ounces per Ton.
Value of raw ore	45·9	...	0·77
Value of roasted ore, minus soluble salts ...	50·0	...	0·84
Increase in value	4·1	...	0·07
" "	8·8 per cent.		9·1 per cent.

From this statement it would appear that the loss of gold in chloridizing-roasting in the Stetefeldt furnace is somewhat less than that of silver. The difference, however, in the increase of value between silver and gold is only 0·3 per cent., and within the limits of errors in sampling and assaying.

13.—*The Chlorination of Silver by Roasting in the Stetefeldt Furnace.*—The so-called chlorination-tests are made by treating a sample of roasted ore with a solution of sodium hyposulphite and assaying the tailings. In the following some of the older statistics on chlorination are given that answer the purpose just as well as more recent ones, which latter the author does not happen to have on hand.

Surprise Valley mill, Panamint, California.—Chlorination-tests made from September 19th to October 23rd, 1875; certified by Mr. C. Weberling, assayer and superintendent. In 96 samples, the following percentages of chlorination occur:—

Per Cent.	Times.	Per Cent.	Times.
85	1	92	18
87	1	93	24
89	1	94	26
90	3	95	12
91	7	96	8

The two low samples of 85 and 87 per cent. were caused by having a new labourer on the furnace, who had never fired it before, the regular fireman failing to be on shift.

Manhattan mill, Austin, Nevada.—Chlorination-tests made from November 1st to December 24th, 1877; certified by Mr. F. E. House, assayer. In 198 samples, the following percentages of chlorinations occur:—

Per Cent.	Times.	Per Cent.	Times.
88	7	92	28
89	28	93	15
90	49	94	—
91	68	95	3

The same mill. Monthly averages of chlorination-tests from October 1st, 1874, to September 30th, 1875; obtained from Mr. Alexander Trippel:—

	Per Cent.		Per Cent.
1874.—October	90·3	1875.—April	90·8
„ November	89·2	„ May	91·6
„ December	91·1	„ June	92·8
1875.—January	89·8	„ July	92·3
„ February	90·0	„ August	91·8
„ March	90·6	„ September	91·5

Ontario mill, Park City, Utah.—Chlorination-tests during July, 1881; copied from the assay-book; Mr. Joseph E. Galigher, superintendent of the mill; Mr. C. W. Watkis, assayer. In 58 samples, the following percentages of chlorinations occur:—

Per Cent.	Times.	Per Cent.	Times.
88	1	92	13
89	1	93	21
90	2	94	9
91	8	95	3

The same mill. Average chlorination-tests from March to September, 1882, according to the Russell method; furnished by Mr. E. H. Russell, assayer:—

	Per Cent.		Per Cent.
1882.—March	92·0	1882.—July	93·0
„ April	91·3	„ August	92·2
„ May	92·9	„ September	91·4
„ June	92·5		

The same mill. Chlorination-tests, according to the Russell method, from October 12th, 1882, to January 1st, 1883; furnished by Mr. E. H. Russell, assayer. In 131 samples, the following percentages of chlorinations occur:—

Per Cent.	Times.	Per Cent.	Times.
87	1	93	46
90	2	94	33
91	10	95	9
92	30	96	—

Lexington mill, Butte, Montana.—Mr. A. Wartenweiler, superintendent; Mr. G. C. Carson, assayer; official report. The Lexington ore contains more or less native silver, hence the results of amalgamation are a better standard for the work of the furnace than chlorination-tests:—

Month.	Furnace. No.	Chlorination. Per Cent.	Left in Tailings. Per Cent.
1882.—December ...	1 ...	82·9 ...	10·0
" " ...	2 ...	85·1 ...	11·8
1883.—January ...	1 ...	85·9 ...	9·9
" " ...	2 ...	85·9 ...	10·8
" February ...	1 ...	86·9 ...	7·4
" " ...	2 ...	86·0 ...	8·5
" March	1 ...	89·9 ...	7·8
" "	2 ...	90·1 ...	8·9
" April	1 ...	92·6 ...	6·1
" "	2 ...	92·5 ...	6·5
" May	1 ...	93·8 ...	5·5
" "	2 ...	94·6 ...	5·3

If chlorination-tests are made separately on samples of roasted ore immediately after discharging the same from the shaft and from the dust-chambers, they show a great difference in favour of the dust, provided the ore is of such a character that it requires heap-roasting on the cooling-floor. The reason is that the ore in the dust-chambers has already undergone a heap-roasting, because it is allowed to accumulate and remain there for many hours before a charge is drawn. On the whole, however, the ore roasted by the auxiliary fire-place shows slightly higher chlorinations than the ore roasted in the shaft, *i.e.*, after heap-roasting is finished.

14.—*Distribution of Roasted Ore in different Parts of the Stetefeldt Furnace.*—The distribution of the ore in different parts of the furnace depends: (1) On the fineness of crushing; (2) on the character of the ore; (3) on the draught; and (4) on the quantity of ore going to the furnace. It can be easily seen how these conditions affect distribution. As a rule no statistics regarding this question are taken in mills. The author, however, made some observations at the Ontario mill. For a period of ten days the ore discharged from the shaft, the flue below the auxiliary fire-place, the first six dust-chambers, and the last six dust-chambers, was weighed, and the results are recorded in the table below:—

	Shaft.	Flue below Auxiliary.	First Six Chambers.	Last Six Chambers
If the value of the raw ore be reckoned at 100, the value of the roasted ore, minus soluble salts, was	89 ...	109 ...	114 ...	112
If the total weight of the roasted ore be reckoned at 1,000, it was distributed as follows:	317 ...	561 ...	112 ...	10
If the silver in the roasted ore be reckoned at 1,000, it was distributed as follows:	306 ...	571 ...	114 ...	9

The ore, at the time, contained a considerable percentage of sulphides, which made it necessary to use a strong draught in roasting.

15.—*Labour.*—One man, in an 8 hours shift, attends to the firing and general supervision of a Stetefeldt furnace, irrespective of the quantity of ore roasted. In case gas-fuel is used, he charges and takes care of the Taylor gas-producer. The labour necessary for discharging, and manipulating the roasted ore on the cooling-floor, is, of course, dependent on the output, and is proportionately the same as with other roasting-furnaces.

16.—*Fuel.*—The quantity of fuel consumed, per ton of ore, is principally a function of the number of tons roasted per day, *i.e.*, it rapidly decreases with increase of tonnage; hence the economy of using furnaces of large capacity. Another, but much less effective element, is the percentage of sulphur in the ore, *i.e.*, oxidized ores require more fuel than ores containing pyritic minerals. The table below gives a good illustration of this :—

Furnace at	Tons of Ore Roasted per day.	Coal Consumed in the Taylor Producer per Ton of Ore. Pounds.	Wood Consumed per Ton of Ore. Cords.
Ontario mill...	40 ...	225 ...	0·19
Marsac mill	70 ...	142 ...	0·13
Aspen mill	90 ...	117 ...	—

The last column refers to the consumption of wood before gas was introduced.

The coal consumed at the Ontario and Marsac mills comes from the same mine; that used at Aspen has practically the same caloric effect as the coal consumed at the former mills.

The ore at the Ontario mill has been roasted at a higher temperature after the introduction of gas than was formerly the case with wood. Of the ores roasted, the Aspen ore is the highest, and the Marsac ore the lowest in sulphur.

Since the introduction of gas at the Ontario mill, a saving in cost of fuel for roasting (as compared with wood) of 2s. 4d. (56 cents) per ton of ore has been effected; and at the Marsac mill the saving is 1s. 8½d. (41 cents) per ton of ore.

In conclusion, the following facts will be of interest. The Stetefeldt furnace has roasted successfully so-called dry silver-ores of great diversity in character and richness. The ores treated have varied between 20 and 250 ounces of silver per ton. Oxidized ores, if entirely free from sulphides, require for good chlorination the addition of pyrites or pulverized sulphur. One-half per cent. of the latter, or 1 per cent. of the former, will generally effect the desired result, except when the gangue

contains carbonates of lime or magnesia which, during roasting, are converted into caustic lime or magnesia. Thus, *e.g.*, the Aspen ore,* with 11 per cent. of lime (CaO) and 4 per cent. of magnesia (MgO), requires the addition of sufficient pyrites to bring up the sulphur in the charge to 8 per cent., in order to counteract the deleterious effect of the lime and magnesia. Oxidized ores free from lime chloridize well without the addition of sulphur if they contain oxides of manganese, which was the case of the Northern Belle mill. So far as the percentage of salt is concerned, no special experiments have been carried out to determine whether the Stetefeldt furnace can chloridize silver-ores with materially less salt than other furnaces. The percentage of salt necessary for good work depends entirely on the character of the ore. The baser the ore, especially the more zinc-blende present, the greater is the quantity of salt needed. Ores in the Panamint mill have been chloridized as high as 96 per cent. with only 3 per cent. of salt, while at the Ontario mill it is found profitable to use 15 per cent. of salt.

Mr. A. G. Charleton (London) wrote that the members were greatly indebted to Mr. Stetefeldt for a very clear account of the construction of his furnace, a faithful and impartial description of its applications, and for bringing to the notice of the members various points of interest connected with its operation. In these days when reduction of working expenses and extra saving of product are objective points which metallurgists endeavour to realize, the application of producer-gas to the roasting of silver-ores, which Mr. Stetefeldt first initiated (effecting, as he stated it has done, a marked saving in cost) may be looked upon as a valuable advance in scientific achievement in this branch of the mining industry. The author refers to the employment of the Taylor gas-producer for this purpose, but according to Mr. Geo. W. Goetz,† "recent reports show that the Wellman producers work better, besides costing 50 per cent. less, than Taylor producers of equal capacity." Mr. Goetz states that Indiana and Illinois coals cannot be used in the Taylor gas-producer on account of the large size and hardness of the clinkers produced. A similar difficulty Mr. Stetefeldt states,‡ was encountered in running the Taylor gas-producers at Aspen with coal leaving light and

* The analysis of Aspen ore, given previously, refers to the pulp going to the Stetefeldt furnace, and includes the pyritic ore added.

† *Trans. Am. Inst. Min. Eng.*, vol. xxiii., page 587.

‡ *Ibid.*, page 136.

infusible ashes when employing Colorado Sunshine coal alone, and at the Marsac mill with coal mined at Coalville, Utah. For this reason the Marsac gas-producer is supplied with the dearer Rocksprings coal, and the Sunshine coal used at Aspen is mixed with two-thirds of its weight of Newcastle (Colorado) coal. The average composition of these coals (with which the Taylor gas-producers work well) is given as follows:—

	Aspen. Per Cent.	Marsac. Per Cent.
Water	2·0	7·0
Volatile matter	37·4	36·0
Fixed carbon	44·8	53·3
Ash	15·7	3·5

Mr. Stetefeldt also says that "for insulating the gas-tubes in the Ontario mill plant, they will be first covered with thin corrugated iron, over which a coating of asbestos-magnesia will be spread." Troughs of sheet-iron filled with mineral wool were first used at the Marsac and Aspen mills for cheapness. Provision has to be made for removing tar and soot from the pipes, and Mr. Stetefeldt seems to be of opinion that there is little fear of over-heating or burning the pipes if spiral-weld steel-tubes are used in place of riveted sheet-iron. Mr. G. W. Goetz and Mr. W. H. Blauvelt, on the other hand, recommend the use of pipes fitted with a refractory lining as being superior in their opinion to spiral-weld steel-tubes; alleging in favour of the former that a proper arrangement of draught permits the whole system to be burnt out perfectly clean, with but little delay and no labour; whilst the lining of the pipe largely prevents strains from expansion and contraction, and diminishes very greatly the need of frequent repairs. The weight of such pipes is certainly, however, an objection, nor is it practicable to line them if of small diameter. In the somewhat exceptional case of an ore requiring to be submitted to a long and gradually increasing temperature, before salt is added, for chloridizing-roasting, difficulties are met with in employing a furnace of the Stetefeldt class, and he (Mr. Charleton) scarcely thought that it would be likely to be successful in roasting heavy pyritic ores preliminary to other treatment, but it is undoubtedly very effective for the chloridizing-roasting of silver-ores, preparatory to lixiviation or amalgamation, if they did not contain over 8 or 9 per cent. of sulphur. He (Mr. Charleton) agreed with Mr. Stetefeldt's remarks that it was not necessary to crush ores finer for roasting in a Stetefeldt than in other types of furnace, and if the silver minerals in an ore are of no great density, and are decrepitated by heat, the ore could be crushed coarse without endangering the subsequent roasting; but if the principal silver

minerals are of great density and did not decrepitate, it was of great importance to crush the ore fine. The difference between crushing through a No. 20 as compared with a No. 40 mesh screen has been known to make a difference in the chlorination result of 27 per cent., besides taking a much longer time.

Mr. D. A. Louis (London) said that shaft furnaces had been tried for roasting pyritic ores, but had never proved very successful. Firstly, the contact was generally not sufficiently long; in the Gerstenhöfer furnace (still, or at least until recently, in use at Swansea), however, the contact was comparatively prolonged, the operation of roasting in it was therefore slow, and its chief use was to reduce the percentage of sulphur to about 8 per cent.; the products of combustion in this case being suitable for the manufacture of sulphuric acid. With most other shaft furnaces not only was the contact too limited, but the atmosphere was generally so charged with products of combustion from the fuel that it was rendered very ineffectual as a roasting atmosphere, and therefore not only was the roasting of the ore very imperfect, but also the gaseous products of the roastings became so dilute, as regards their sulphurous contents, that they were useless for the manufacture of sulphuric acid. These remarks apply even to furnaces provided with shelves to break the fall, and thereby improve and prolong the contact of the particles of ore with the atmosphere; hence there seemed little hope of a furnace with a plain shaft of the Stetefeldt type ever being successfully used for roasting pyritic ores. It must not be forgotten that the mineral had to be finely crushed for the Gerstenhöfer furnace, that the fuel was the sulphur of the ore, and that an artificial air-supply was resorted to. The Fauvel shaft furnace for roasting pyrites had recently been described, in which provision had been made to keep the air-supply for the roasting separate from the products of combustion from the furnace fire, and it was said that this furnace had proved successful.

Mr. C. A. Stetefeldt wrote that the use of spiral-weld steel-tubes for conducting producer-gas had proved a complete success at the Marsac and Ontario mills. In the latter mill they had been in use about a year, and in the former for two years. It has been found advantageous, however, not to provide them with an insulating covering. If, during cleaning, a tube became red hot by the burning of soot, this was at once observed, and the tube was closed until it cooled down. Using this precaution, the spiral-weld tubes were very durable and required no repairs for years. Expansion and all strains were taken up by expansion-joints of simple construction. For reasons which the writer need not explain in

detail, it would have been impracticable to use pipes lined with a refractory material on account of their weight. At the Ontario mill, the introduction of gas-fuel, for drying and roasting the ore, saved about £13 per day, as compared with the cost of the wood which was formerly used.

The CHAIRMAN moved a vote of thanks to Mr. Stetefeldt for his interesting paper, which was agreed to.

Mr. John Morison's paper on "Walling and Sinking Simultaneously with the Galloway Scaffold" was then read.

WALLING AND SINKING SIMULTANEOUSLY WITH THE GALLOWAY SCAFFOLD.

By JOHN MORISON.

So far as the writer is aware no successful attempt has been made up to the present time, with the exception of the one about to be described, to wall shafts during the operation of sinking without withdrawing the men from the bottom whilst walling was proceeding.

The present paper is a record of the operation, which has been carried out successfully, of walling a shaft, 20 feet in diameter and 1,650 feet in depth, the shaft being lined from top to bottom, with the exception of small projections of hard stone under several of the walling-crib foundations. In places where the stone was quite sound, these were left in and dressed; in other places where the foundation was not so good, the foundation-cribs were underset with the under course of brickwork right up to the crib.

It will be seen from Figs. 1 and 2 (Plate VIII.) that the scaffold or cradle is suspended by four ropes in double purchase, these being 5 inches in circumference, and of Bessemer steel. One end of these ropes is made fast at the surface by attachment to a heavy screw, which serves for purposes of adjustment in the event of the ropes riding unevenly on the drums. The other end passes round the wheel on the cradle and over another wheel on the winding-frame, and thence to the crab-drum. Four drums are thus required on the crab-engine.

The part of the rope between the scaffold and the pulley on the frame is used for a guide-rope to the rider, and serves to guide the kibble up from and down to the cradle. When the kibble approaches the cradle the engineman slows until he lifts the rider upon an indiarubber buffer seated upon the top of the socket of the winding-rope. The rider is provided with a bush (Figs. 5 and 6, Plate VIII.), through which the winding-rope runs, and which also serves partially as a rest for the buffer referred to. Resting upon the cradle, where the two legs of the rider seat themselves, indiarubber buffers also surround the guide-rope to minimize as far as possible the shock of the rider landing on the cradle.

This arrangement, so far as the use of the cradle, ropes, and rider for the purpose of guiding and steadying the kibbles, was, the writer

believes, invented by Mr. W. Galloway, of Cardiff, some fifteen years ago, but walling simultaneously with sinking by means of it has not been heretofore practised, and in order to do so the cradle must be specially designed and substantially built for the purpose.

The cradle, as designed by the writer and used at Newbattle colliery, consists of a working floor (Fig. 3, Plate VIII.) and a protecting roof (Fig. 4, Plate VIII.). Between these there is ample height for men to work. The centre of the cradle contains an opening which provides space for two kibbles passing each other. This opening is fenced by sheet-iron, $\frac{1}{4}$ inch thick and $6\frac{1}{2}$ feet high, bolted to the six upright angle-bars and hangers.

The floor stage is formed by a 4 by 4 inches by $\frac{1}{2}$ inch mild steel angle-bar turned to a true circle, supported on and fastened to the bottom framing or flooring, which is constructed of 5 by 5 inches by $\frac{5}{8}$ inch steel angle-bars. The floor is covered with planking 5 inches thick.

A door or hatchway is hinged to the floor, and is raised or lowered by the block-and-tackle fastened by shackles to the door and the framing of the scaffold. The door is recessed to allow of its closing on the air-boxes and pipes. Hatchway doors are also left on the other side of the cradle to permit of the brick kibble—the arrangement of which is hereafter described—being lowered through if required.

The roof is formed of 5 by 5 inches by $\frac{5}{8}$ inch steel angle-bars, covered with $\frac{3}{8}$ inch sheet-iron plates. The framing of the roof where the suspending wheels carry the whole of the cradle, is constructed of double 5 by 5 inches by $\frac{5}{8}$ inch steel angle-bars riveted together.

The bottom and top of the scaffold are connected together by four corner steel angle-bars 5 by 5 inches by $\frac{3}{4}$ inch bolted to the top and bottom framing. Four stays are placed to the four upright corner angle-bars for the purpose of supporting and stiffening the top or roof framing. Two $1\frac{1}{2}$ inches tension-rods are secured to the double angle-bars and to the outer ring of the floor for the purpose of strengthening and carrying the floor. A sheet-iron ring, formed of $\frac{3}{16}$ inch sheet-iron, is bolted to the circular framing and forms a fence round the scaffold 18 inches high. The difference between the diameter of the pit and the upper side of this ring is about $1\frac{1}{2}$ inches, or an opening of $\frac{3}{4}$ inch exists between the brickwork and the fence. Fending-plates are bolted to the bottom of the scaffold to guide a swinging kibble through the opening in case of accident. The weight of the scaffold is about $8\frac{1}{2}$ tons, and, when loaded with bricks, lime, and workmen, the working load is about 20 tons.

As already described, the cradle is hung by four 5 inches ropes, in double purchase. In addition to these, another guide rope, made fast at the top, as previously described in the case of the other guides, and looped down the shaft, is provided. Upon this is hung a pulley, supporting the water-tank and scaffold, with two pulsometers and suction-pipes and discharge-pipes into the cistern. Valves and hoggers for running the water into the water-barrels are also provided. The double rope referred to is brought through the cradle, and the loose end is led on to one of two drums on the winding-engine. The other drum is provided with a winding-rope, and the kibble used with this rope runs with a rider, with the pump suspending-rope as a guide on each side, and supplies the scaffold with bricks, lime, etc.

Both drums on the winding-engine are clutched so that when firing shots in the bottom, the pulsometers and scaffold, etc., after being disconnected from the steam-pipe, may be hauled up out of danger. It may be mentioned that this arrangement of loading the water-barrels proved very satisfactory and economical. No baling was required, and after week-end stoppages the water was rapidly taken out. About 200 gallons per minute from a depth of 900 feet was at one time wound out of the pit-bottom for several weeks, while sinking progressed and pumps were fixed.

The mouth of the sinking-pit was covered by two pairs of folding-doors. In the case of winding water, a tank provided with wheels was run on to the doors and the water-barrel in seating itself on to the tank engaged a projection which struck open the bottom valve and discharged the water. In tipping *débris*, a shoot built of steel plates and mounted on wheels was run on to the doors between the two kibbles, so that either kibble could be tipped into it. The shoot delivered the *débris* into tipping-wagons. The kibbles, being provided with trunnions, it was not necessary to detach them from the steadiment of the guide-ropes at the top. The platform upon which the doors rested was considerably above the ground-level, in order to permit of the *débris* being put into wagons.

At the ground-level, one pair of similar doors were placed which were opened to permit of the passage of the kibble containing bricks, lime, etc., and closed whilst the kibbles were being loaded. In both cases the doors were recessed to the size of the ropes, so that they closed tightly over the guide-ropes and easily over the winding-ropes.

The arrangement for guiding the kibbles to the position of the scaffold permits of a comparatively high speed of winding, and also enables double kibbles to be used with great safety. The sinking-engine in the instance described could wind the kibble from the depth of 1,650 feet in 55 seconds.

In walling, a roll of canvas or brattice-cloth was packed between the outer ring on the scaffold and the shaft side, so that there was absolutely no opening. The hatch or doorway, where it closed against the air-boxes, pipes, etc., was also carefully packed with canvas before commencing to build the walling. Sheet-iron plates were laid over the hatchway where the brick kibble was tipped.

The bricks and lime were sent down in kibbles provided with trunnions and the material was tipped without detaching the kibble from the rope. At the top of the pit, the empty kibble was landed on to a bogey, detached from the rope, and a full kibble hung on in its place.

When walling, three bricklayers with three labourers, and a sinker in charge, were the most convenient number to work on the scaffold, and in ordinary work these workmen would build a five feet length complete.

The scaffold was considered safe from damage by shots in the pit-bottom when at a distance of 60 feet from the bottom.

Crib-beds were laid as the foundation was found suitable, and lifts were taken varying from 90 to 240 feet.

The timbering was made with cribs built of 11 by 3 inches planks fished together at the segments by double covers 11 by 1½ inches. These were put together and marked at the surface and lowered down in segments. In soft strata, the cribs were placed 2½ feet apart, the backing deals being 5 feet long. This arrangement, in drawing the timber, provided means of supporting loose stone, as by leaving in the backing deals, these, when the under crib was drawn, were supported by the two upper cribs—when the middle crib was drawn, by the brickwork and the upper crib—and when the upper crib was drawn support was entirely afforded by the brickwork.

In drawing timber it was found to be unnecessary to bring up the sinkers, except in very bad ground.

In forming a crib-bed, the sinkers left the stone rough hewn out, leaving the levelling and dressing to be done off the cradle. This work was also done without accident, and without withdrawing the sinkers.

It was also found possible to form pump-rooms and lodgments in the side of the shaft, by taking the scaffold to the point required and winding the *débris* with the brick kibble, and this was done in several instances, no time being lost in sinking.

The cradle was usually raised during the time when the men were changing shifts.

The folding-door permitted of the cradle passing any obstructions or tight places in the shaft, and two or three men usually rode upon it to clear it of any such obstructions when raising or lowering.

A lift of concrete coffering about 90 feet high and 28 inches thick was put in from the scaffold very conveniently. The ordinary brickwork was 10½ inches thick.

After being fairly put to work, there was no trouble in working the scaffold.

No accident occurred through its use, although two occurred with the brick kibble-rider, which it may be useful to record. One of these occurred through the rider sticking on the guide-rope and afterwards coming down. The cause of this accident was never satisfactorily ascertained, but after its occurrence the bushes on the rider, which are of beechwood, were given more clearance, and allowed to be ½ inch slack on the rope. The second accident was caused by some sinkers, who, whilst working in the shaft, lashed up the rider on the rope some distance above the kibble. Owing to insufficient lashing the rider fell away. On both occasions a fatal accident occurred.

The advantages which the writer has observed in the use of the cradle are as follows:—

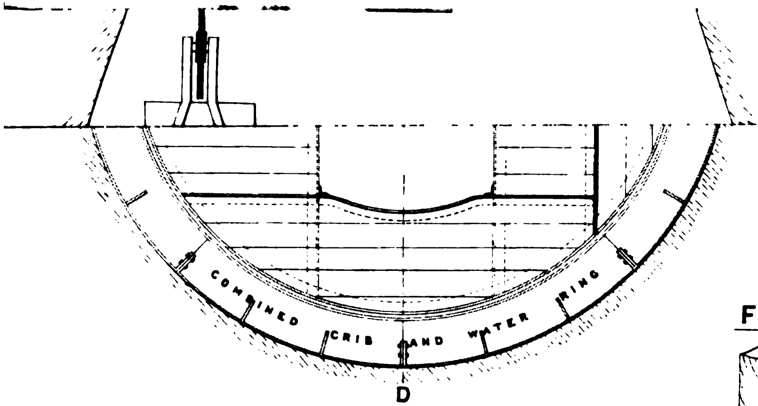
1. It permits of quick winding with double kibbles with great safety.
2. No time is lost through the sinkers being withdrawn to wall.
3. The brickwork can be better done by skilled bricklayers and at less cost than by sinkers.
4. In forming any necessary recesses or roads off the shaft side, no delay in sinking need be incurred.
5. The suspension of a substantial structure in the shaft affords considerable protection to the men working in the pit-bottom.

With reference to the latter advantage, upon several occasions when material had dropped accidentally down the shaft, it landed on the roof of the scaffold and caused no damage; and especially when working within a moderate distance from the bottom, the protection was found of great advantage.

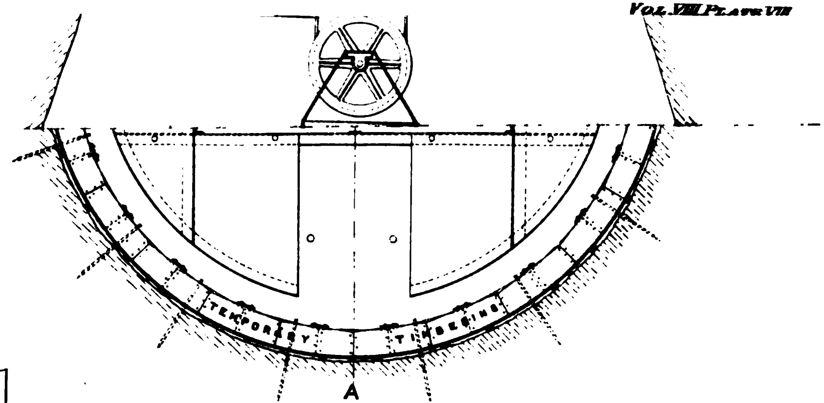
The drawings (Plate VIII.) accompanying this description of the apparatus are detailed enough, the writer thinks, to render unnecessary a fuller description of the arrangements.

Mr. Henry Lawrence (Durham) said that the author of the paper was in error in assuming that the Galloway scaffold had not been previously used for sinking and walling simultaneously. He understood it had been used at the Llanbradach colliery, when Mr. Galloway was manager.

Federated Institution of Mining Engineers
Transactions 1894-5



PLAN OF FLOOR OF CRADLE.



PLAN OF ROOF OF CRADLE.

FIG. 5.

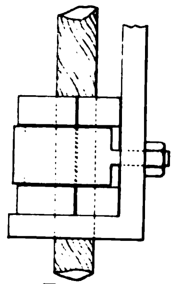
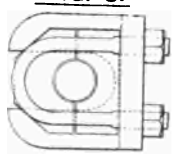


FIG. 6.



GLAND AND BUSH FOR RIDER

...th of England Institute of Mining & Mechanical Engineers
Transactions 1894-5

Andw Reid & Compy Ltd Newcastle-on-Tyne

Mr. A. L. Steavenson (Durham) said that the writer of the paper was to be congratulated on the successful results he had obtained. "All's well that ends well," but he thought as a rule it was undesirable to attempt to do two things at once. The principle advocated in the paper would scarcely be applicable to shafts in which there were large feeders of water. No doubt provision was made for the removal of powder-fumes and smoke from the shaft by proper ventilation, but this was not described in the paper.

The President suggested that a comparison of the time occupied in sinking and walling by the ordinary process and by that described would be of interest. He thought care should be taken with the new system to avoid accidents.

Mr. W. B. Scott (H.M. Inspector of Mines) said that in addition to the comparison suggested by the President there were one or two other points of interest which might have been discussed with the paper. He remembered that twenty-one years ago in Staffordshire, a rider was constantly used for steadying the kibble. The method of covering a shaft with hinged doors was, he thought, old-fashioned and awkward as compared with the usual method of a sliding platform. The author stated that "crib beds were laid as the foundation was found suitable, and lifts were taken varying from 90 to 240 feet." Perhaps the author could afford further information on this question. He thought it would have been possible to avoid the two fatal accidents by putting a stop for the rider.

Mr. Henry Lawrence thought he could answer the question of the last speaker as to the crib-beds. He took Mr. Morison to mean that a crib was put in where they could get a good sound bed for it—a good bed of rock—they then proceeded to wall for 90 or 100 feet, which was called a lift, before putting in another crib.

Mr. Spruce (Tamworth) thought that there must be some mistake as to fixing the cribs even 90 feet—not to say 240 feet—apart. In his long experience he had never seen any ground which could be left unprotected for any such length. The principle of using a rider with the kibble was not so new as the author of the paper seemed to think; he had used a similar arrangement as far back as 1850.

Mr. H. Lawrence said it would be interesting to know at what distances apart Mr. Spruce would place the crib-beds when walling. When putting in cast-iron tubbing, it sometimes happened that wedging cribs were placed 50 or 100 feet apart.

Mr. Spruce replied, as often as necessary.

Mr. W. B. Scott said that an accident in South Wales was due to a long length of the shaft being left without walling, and so allowing a mass of rock to fall out. He had seen ground that required crib-beds being placed at intervals of only four feet.

Mr. Henry Lawrence remarked that the accident in South Wales was supposed to have been caused by a blown-out shot. He had visited the colliery, and was fully acquainted with the particulars.

Mr. W. B. Scott said he understood that the men were killed by a stone falling from the side of the shaft. In any case, the closer they kept the casing to the back of the sinkers the better.

Mr. John Morison wrote that he believed that the statement made in his paper was quite correct, that the operations recorded were the first instance of sinking and walling simultaneously without withdrawing the men from the pit-bottom. Possibly experiments may have been entered into, but no suitable plant had hitherto been brought under notice in the *Transactions* of The Federated Institution of Mining Engineers. The criticism that "all's well that ends well" might be taken to express considerable doubt in Mr. Steavenson's mind as to the safety of the process; but the writer maintains that the arrangement, so far from being a source of danger formed a considerable protection to the sinkers, and that there was absolutely no danger of walling material falling to the pit-bottom. The total quantity of water encountered in the shaft in question was 500 gallons per minute down to a depth of 1,020 feet, and although the quantity was not large the depth of water-bearing strata was considerable, and the writer thinks that the arrangement would be equally applicable with large quantities of water. The ventilation of the sinking shaft was effected by means of a forcing-fan blowing air down pipes into the pit-bottom, and by the exhaust air from a small air compressor. The writer is aware, as noted by Mr. Scott, that apart from the application of riders along with the general arrangement described in the paper, there was no special novelty. The comparative advantages of different methods of covering the shaft are of course dependant upon the constructive details, and it is therefore hardly fair criticism to classify any arrangement as old-fashioned and awkward from the fact of the construction proceeding on any particular principle. It would have prolonged the paper, which was specifically limited to the description of the walling arrangements, to an inordinate extent to describe in detail the whole of the sinking arrangements. The double-hinged doors were very rapid in use, and their safety is best vouched for by the fact that they were used during the whole time of sinking without accident. The statement that "crib beds were laid,"

etc., was correctly construed by Mr. Lawrence, in so far as he explained that a crib was put in when a good sound bed was got for it. The writer is aware that unusually long lengths of walling (taken from crib to crib) were used in the shaft referred to, and he is of opinion that with a good system of timbering very bad ground may be securely left between the crib beds. The drawings (Plate VIII.) accompanying the paper give full details of the timbering, in anticipation of questions upon this point, and the writer holds that with such a system a shaft can not be described as unprotected. The writer did not refer to the comparative times and costs of walling and sinking by the process described, and by the usual process, it being obvious that the difference or time saved is practically the whole of the time usually occupied in walling, seeing that it is never necessary to withdraw the sinkers. The walling will, the writer thinks, be done cheaper by skilled bricklayers than by sinkers, and the complete nature of the apparatus is also favourable to such a result, otherwise the cost of walling would be the same whether the walling was done with the sinkers in the bottom or in the ordinary way. Owing to the saving of time it is obvious that there must be a considerable saving in the standing expenses of the pit-sinking, such as fuel and wages. In every instance the saving in cost would vary, and the amount would be dependant upon the establishment expenses. The cost of more extensive timbering than usual would have to be set against any such saving, although it may be questionable whether similar timbering is not also necessary with shorter lifts of walling. But with a saving in time equal to the whole time usually employed in walling, and which, the writer thinks, may be taken on an average, at one-sixth of the total time of sinking, the saving, especially where there is a heavy establishment, must be very great. In estimating the exact saving, to be obtained in any instance the writer would base the saving on establishment expenses, through shortening of the time occupied, and upon any further contingent saving due to the time saved, and would estimate the cost of walling *per se* to be equal either way.

The PRESIDENT proposed a vote of thanks to the author for his interesting and valuable paper, which was agreed to.

DISCUSSION ON MR. HUGHES' PAPER ON "PHOTOGRAPHY IN MINES."*

The PRESIDENT said that to anyone desirous of taking photographs underground, the paper would be found of great value. Now that the methods of photography were so much improved, excellent pictures could be made of underground workings by ordinary operators.

Mr. M. WALTON BROWN said the difficulty of underground photography was not so much in the manipulation of the apparatus, dry-plates, etc., but in obtaining effective lighting of the objects being photographed.

Mr. A. L. STEAVENSON said that his experience had not been large, but he had found photography in mines of considerable value, and the process was very simple so long as the lights were kept well behind the lens, and ample reflectors were provided. It was, perhaps, somewhat difficult to ascertain the precise quantity of magnesium to be burned in producing the actinic rays.

DISCUSSION ON MR. W. S. GRESLEY'S PAPER ON "SPONTANEOUS COMBUSTION IN COAL-MINES."†

Mr. S. SPRUCE thought it would be found that the seams most subject to gob-fires contained some moisture in the coal. He would like to make a few remarks by way of explanation in regard to the discussion which followed the reading of a paper on this subject two years ago.‡ Unfortunately he was unable to be present at the meeting when his remarks were read, but in the discussion the then President said he did not understand an observation made with reference to taking out 1,400 tons for each foot per acre,§ reducing the liability on the part of the seam to produce gob-fires. The President thought this might mean that nothing would be left to fire, and this was precisely his explanation. Pit fires might occur in the roof or in the floor, but his observations—if he were in order in referring to them—were made entirely in reference to gob-fires and not to fires which might occur otherwise. He was reminded of fires occurring in mines that were not moist, and he had referred to these in his paper‖—one that occurred by the side of roads in the thick coal-seam of South Staffordshire. He thought, generally speaking, that if attention was paid in the direction which he had indicated in his paper—to careful packing and the removal of small slack from the mine—gob-fires would be of much rarer occurrence than they had

* *Trans. Fed. Inst.*, vol. vii., page 164. † *Ibid.*, page 206. ‡ *Trans. Fed. Inst.*, vol. v., page 20. § *Ibid.*, page 28. ‖ *Trans. North Staffs. Inst.*, vol. viii., page 38.

unfortunately been hitherto. He would like to make another remark; there seemed to be a little contention about turning the ventilating current upon a gob-fire, and in the previous discussion Mr. Binns thought that he (Mr. Spruce) seemed to think they were going to take a volume of air and pour it upon the gob.* He meant that he did not think any additional air passed through the mine would assist in staying an actual gob-fire. Ventilation must of course go on and regard must be had to the lives of the workmen employed and for the safety of the mine, but its action was only to increase the fire.

Mr. W. F. Howard (Chesterfield) said that Mr. Binns had thoroughly explained that the admission of air he advocated was before the gob-fire took place, but afterwards all air should be kept from the fire.

Mr. D. A. Louis (London) stated that at the recent meeting of the British Association Mr. Thomas had drawn attention to a possible relationship between the hygroscopicity of the coal and its liability to spontaneous combustion, and he (Mr. Louis) was of opinion that any such relationship would more probably be found to be due to the hygroscopicity being in a way a measure of the purity of the coal, than to its indicating the presence of hygroscopic compounds capable of giving rise to spontaneous combustion. It should be remembered that *inter alia* the question of ventilation in its bearing on spontaneous combustion was discussed last year at the Glasgow meeting, and many points now raised was then considered.

The President thought it might be well in the future to direct their attention to the causes of these gob-fires, for if they knew the real causes they would be better prepared to take steps for their prevention, but at present they seemed to be involved in considerable doubt and mystery.

STUDENTS' MEETINGS.

The Secretary announced that the Council were making arrangements for Students' Meetings, limited to members under twenty-five years of age, that a prize would be offered for the best paper on a chosen subject, and that further particulars would be announced in due course. He invited written suggestions from members as to the place and date of the first meeting, which would be held during the course of next year.

The following paper by Mr. Morgan W. Davies on "Timber Bridges and Viaducts" was taken as read:—

* *Trans. Fed. Inst.*, vol. vi., page 412.

TIMBER BRIDGES AND VIADUCTS.

BY MORGAN W. DAVIES.

The subject of this paper, it may be suggested, diverges widely from the conventional category of contributions to the Institution's proceedings, which although embodying a comprehensive record of experience and research, have so far been devoted to topics more closely allied with mining. It must, however, be borne in mind that the duties of a mining engineer are daily becoming more extended, and by reason of an ever-growing tendency in every branch of industry to concentrate and unite small undertakings into larger ones, the scope of the administration must necessarily become more extended. It, therefore, frequently happens that the administrative head of a large mining establishment is not only responsible for the technical supervision of the mining operations, but also for the direction and control of the general *ensemble* of the undertaking, often including the laying out, construction, and maintenance of many miles of private railways, roads, bridges, and other accessory work.

In view of such contingencies it is thought that an occasional paper of this nature may be of interest, if only for the purposes of reference, because it has not fallen to the lot of every mining engineer to be associated with works of the kind.

Again it may be advanced that to advocate the construction of timber bridges at the present moment, when iron and steel are being so rapidly substituted for other materials in almost every structural work, is the outcome of a very antiquated idea and in effect putting back the hands of the clock fifty years. While fully recognizing the permanency of structures built of iron and steel and appreciating the various qualities and forms in which those materials are being manufactured and shaped for all constructive purposes on the one hand, and acknowledging on the other hand the more perishable nature of timber structures, one must admit that there are instances daily arising where the comparative advantage of an iron or steel bridge over a timber bridge is not so much the question as to have a timber bridge or no bridge at all. This is especially true in regard to colliery railways where the works are not expected nor required to be of so permanent or substantial a character, or in connexion with the development of foreign railways frequently

passing through localities where timber is available in abundance. The duty and instinct of an engineer, under such circumstances, should be to utilize in the best manner the resources at his disposal, and to make a good job of whatever materials he may have at hand. Of all constructive materials there is probably none that lends itself so readily to every purpose as timber. It can be converted to use from the raw state and put together by comparatively unskilled hands, and if judiciously employed and proportioned for the duties it has to perform whether alone or in combination with iron or steel it makes a good strong structure.

It is a well-known fact, borne out by ample experience, that timber structures if built of selected and well-seasoned wood and properly cared for will last thirty or forty years, in proof of which it may be cited that many of the timber bridges and viaducts put up by that eminent engineer, Mr. Brunel, on the Great Western Railway from forty-five to fifty years ago are still in existence, and efficiently serving the requirements of the present day traffic, notwithstanding the fact that it is considerably heavier having regard to weight of rolling stock, etc., than that which they were originally intended to carry.

The timbers used for constructive purposes in this country are pine or fir imported principally from the Baltic ports and from North America. The Baltic timbers are known by the ports from which they are imported, viz., Stettin, Dantzig, Riga, and Memel. These timbers are procurable in lengths up to 50 feet, and from 15 to 17 inches square. The American timbers are red and yellow pine, which are principally imported from Quebec. They may be had in balks up to 50 feet in length, but not exceeding 14 inches square. Of all these timbers long-leaf yellow pine of mature growth is beyond a doubt the best timber for bridge-building that can possibly be obtained, but unfortunately it is now very scarce since all the primeval forests have been cut down, and there is nothing but young timber left available.

Pitchpine, which is derived from the Southern states of North America, and imported from Pensacola and Mobile, is obtainable in abundance to almost any dimensions, ranging up to 80 feet in length, and to 20 and 22 inches square. Pitchpine when new is a very fine timber, but with age, and as the resin dries up, it becomes very brittle and it is also subject to dry rot. Notwithstanding these defects it is largely used in bridge-building.

Oak is used in small quantities where the strain it has to resist is one of compression, such as in joggles, keys, wedges, distance-blocks, etc.

The different timbers essentially vary in strength and their capabilities of resisting the several strains to which they may be subject. The subjoined table, compiled from different authorities, sets forth their various resisting properties, weights, and specific gravities:—

Description of Timber.	Specific Gravity.	Weight per Cubic Foot.	Tensile Strength per Square Inch.	Crushing Strain per Square Inch.	Transverse Strength.
			A.	B.	C.
		Lbs.	Lbs.	Lbs.	Lbs.
Red pine	0·512	32·00	10,500	5,395	483
Yellow pine ...	0·437	27·25	10,500	5,375	474
Pitchpine... ..	0·682	42·50	10,500	6,790	495
Larch	0·622	39·00	7,000	3,201	557
Riga fir	0·480	30·00	9,000	5,400	530
Dantzig fir ...	0·708	43·50	9,000	5,400	611
Memel fir	0·553	34·50	9,000	5,400	545
Spruce	0·555	34·50	10,000	6,499	465
Oak, English ...	0·748	46·50	9,000 to 15,000	6,484	710
Oak, Canadian ...	0·802	50·00	10,000	4,231	572

In the above table, the figures set forth in column A represent the force in lbs. per square inch required to tear asunder a beam in the direction of its length, and column B similarly sets forth the force that would compress a pillar or other piece of timber in the direction of its length, until it ultimately failed by the crushing of the material.

Column C sets forth the force whether in the form of a distributed or concentrated load on a beam supported at both ends, that would produce rupture or cause the beam to break across the grain of its fibres.

With these data the breaking weight of a beam of any of the timbers named in the table can be easily calculated by the following simple rules:—

Let B W = breaking weight in pounds.
L = length between supports in feet.
B = breadth in inches.
D = depth in inches.
A B and C = constants given in columns A B and C of the table.

RULE.—To find the weight that would break a rectangular beam when applied at the centre, the beam being supported at the ends—

$$B\,W = \frac{B \times D^2 \times C}{L}.$$

E.G.—What weight applied at the centre of a yellow pine beam 10 feet long between supports and 8 inches wide by 12 inches deep would break it?—

$$B\,W = \frac{8 \times 12^2 \times 474}{10} = 54{,}604{\cdot}8 \text{ lbs.}$$

In the case of a distributed load, the weight that would break a beam would be double that of a load concentrated at its centre and the rule would be—

$$B\,W = \frac{B \times D^2 \times C \times 2}{L}.$$

Having regard to the resistance of timber to compression in the direction of its length; its power of resisting such strains depends upon the proportion of its length to its cross-sectional dimensions. A long pillar, under an excessive load, will first bend and then break at the middle in precisely the same way as it would under transverse strain, whereas a short pillar would fail by the crushing of its fibres alone. The proportion between the length of a pillar and its cross-sectional dimensions is therefore a matter of vital importance.

To ascertain the strength of pillars of medium lengths

Let $B\,W$ = breaking weight in pounds.

a = area of cross section.

B = constant in column B of table.

L = length in feet.

T = least side or thickness.

$$\text{Then } B\,W = \frac{B \times a}{1{\cdot}1 + \dfrac{L^2}{2{\cdot}9 \times T^2}}.$$

E.G.—What load would break a pillar of Memel fir 12 feet long and 6 inches square?

$$B\,W = \frac{5{,}400 \times 36}{1{\cdot}1 + \dfrac{144}{2{\cdot}9 \times 36}} = \frac{194{,}400}{2{\cdot}479} = 78{,}413 \text{ lbs.}$$

The breaking weights calculated by the above formulæ should, whether applied in compression tension or transversely, be ten times the calculated maximum stresses or loads in any member of the bridge, because the strength of wood varies very much in different specimens, and the experiments from which the values given in the table are deduced were made with selected pieces. This margin is called the factor of safety.

Having thus explained in simple form the mode of calculating the breaking weight of beams of the different timbers ordinarily used for bridge-building in this country under such normal conditions of loading as would occur in the case of a bridge, it now remains to furnish rules and examples by which the strains on the different parts can be estimated, and to apply these rules to the proportioning of every part to the strain it has to bear. The strength of a bridge is the strength of its weakest part, and any unnecessary accumulation of material does not in any way add to its strength, but on the contrary detracts from it by reason of the additional weight imposed.

The examples given in the drawings are all selected from actual practice, and in two instances they represent, with slight modifications, structures designed by the author. It has been the author's aim to show the various parts in sufficiently full detail to enable the drawings to be worked from, and as such it is hoped they may be found useful.

Example No. 1.

The illustrations (Figs. 1, 2, 3, 4, and 5, Plate IX.) represent the most simple form of bridge, consisting of a series of longitudinal timbers, supported at different points, and carrying a single line of railway. The spans, five in number, are 20 feet each, measured from centre to centre of piers. Dead or uniform load, 5 cwts. per foot run; live or variable load, 2 tons per foot run. The girders are three in number, composed of built beams, the two outer girders being 26 inches by 8 inches, and the central girder 26 inches by 15 inches.

Principles of Calculation.

The maximum load that can come upon any one span will be 2·25 tons per lineal foot, which, multiplied by the span, will give a distributed load of 45 tons or a concentrated central load of $\frac{45}{2} = 22{\cdot}5$ tons. This weight, which is to be carried on two rails spaced 5 feet apart from centre to centre, one half or 11·25 tons on each rail, will be supported by the three girders in proportion to the respective reactions of the load upon its supports.

Thus the proportion supported by each of the outside girders will be $\frac{11{\cdot}25 \text{ tons} \times 2{\cdot}5 \text{ feet}}{5{\cdot}5 \text{ feet}} = 5{\cdot}11$ tons, and by the central girder $\frac{11{\cdot}25 \text{ tons} \times 3 \text{ feet}}{5{\cdot}5} \times 2 = 12{\cdot}27$ tons.

The maximum weights to be carried by each girder are therefore 12·27 tons by the central girder, and 5·11 tons by each side girder. It is now required to determine what cross-sectional dimensions a Memel fir beam should have to carry this load with a factor of safety of 10. The breaking weight of the beam would thus be 12·27 tons × 10 = 122·7 tons, or 274,848 lbs. Assuming the breadth of the girder = B to be 15 inches then

$$D^2 = \frac{B\,W \times L}{B \times C} = \frac{274{,}848 \times 20}{15 \times 545} = 672, \text{and } D = 25{\cdot}92 \text{ inches.}$$

The actual depth of the girder in the drawing is 13 inches by 2 = 26 inches.

Having regard to the side girders it is needless to calculate their breaking weight because they are, in proportion to the load they have to carry, wider and stronger than the central girder. They have been given

the same depth as the central girder for the sake of uniformity, and it has been necessary to give them an additional breadth to that actually required to bear the strain due to the load upon them for the sake of giving them the necessary stiffness, failing which they would be subject to lateral flexure.

It is now required to determine whether the strength of the piles or columns supporting the structure are sufficient to resist the strain upon them. In this instance again the central pile has to support the greatest load, the proportions being: Weight supported on central pile = 24·54 tons ; weight supported on each side pile × 2 = 20·44 tons ; total weight of one span = 44·98 tons. The piles are 12 inches square, and the length between braces is taken at 8 feet.

$$\text{Then} \qquad B\,W = \frac{5{,}400 \times 144}{1 \cdot 1 + \dfrac{64}{2 \cdot 9 \times 144}} = \frac{777{,}600}{1 \cdot 253}.$$

B W = 620,590 lbs., and safe load = 62,059 lbs. or 27·7 tons, as against 24·54 tons, the actual load.

It is here supposed that the pile has been driven well home, and capable of carrying its intended load with safety. This can be determined by the following formula (Sanders') :—

Let D = set of pile by last blow in inches.
H = height fallen through by ram in inches.
L = safe load which the pile will bear in lbs.
W = weight of ram in lbs.

$$\text{Then } L = \frac{W\,H}{8\,D}.$$

The estimated quantities of materials in this bridge are as under :—

	£	s.	d.
2,061 cubic feet of timber, at 3s.	309	3	0
30 cwts. bolts, nuts, spikes, etc., at 12s.	18	0	0
18 pile-shoes (steel), at 15s.	13	10	0
12½ cwts. cast iron in pile caps, at 6s.	3	15	0
Total cost of bridge	£344	8	0
Cost per foot run	£3	8	10

Example No. 2.

In this instance the illustrations (Figs. 6 to 10, Plates IX. and X.) represent a trussed bridge in which the main beams are aided by two struts abutting against the piers or points of support, and a straining beam.

There are three spans of 36 feet each, and the load to be carried is the same as in example No. 1, viz. :—dead or uniform load, 5 cwts. per foot run ; live or variable load, 2 tons per foot run.

Principles of Calculation.

The span is divided into three sections, as shown in Fig. 6; and the load when uniformly distributed is carried to the points of support in the following manner:—W^1 and W^4 are respectively carried directly by the piers. A C and A″ C″ and W^2 and W^3 are respectively carried and transmitted to the piers by the struts C B and C″ B″.

The main beam may therefore be treated as a beam supported at the four points A, B, B″, and A″, and the maximum bending moment will occur at the middle of either span, that is to say, at the points M′, M″, and M‴. At M″, the beam has the advantage of the support afforded by the straining beam B′ B″, so that the weakest points will be at M′ and M‴.

The maximum strain that can come upon the section A B or B″ A″ will be 27 tons uniformly distributed, or 13½ tons concentrated at the points M′ or M‴.

The load of 13½ tons is supported by three girders spaced 5 feet apart from centre to centre, and, as the rails upon which the load is directly carried are also 5 feet apart from centre to centre, the central girder will carry one-half of the load or 6·75 tons, and each of the side girders one-quarter or 3·375 tons.

It is therefore required to determine the dimensions of a square beam of Memel fir to carry a concentrated load of 6·75 tons, which, with a factor of safety of 10, is equivalent to a breaking weight of 67·5 tons or 151,200 lbs. The length, being one-third of the span, $= \frac{36}{3} = 12$ feet.

$$\text{The square dimensions} = \sqrt[3]{\frac{151{,}200 \times 12}{545}} = \sqrt[3]{3{,}329} = 14{\cdot}78 \text{ inches,}$$

say 15 inches square. The central beam may thus be 15 inches square and each of the side beams 15 inches by 7½ inches, say 15 inches by 8 inches.

It is next required to determine the strain upon the struts C B and C″ B″, and in this instance again the central strut will be taken. The strain on a strut is the weight it carries multiplied by the cosecant of the angle of inclination to the horizon $= \dfrac{\text{weight} \times \text{C B}}{\text{A C}}$.

The weight carried by the central strut C B is one-half of the distributed load on the section M′ M″ = 13·5 tons. The length of the strut measured along its axis is 13·4 feet, and the strain will be

$$\frac{\text{C B} \times 13{\cdot}5}{\text{A C}} = 30{\cdot}17 \text{ tons or } 67{,}580 \text{ lbs.}$$

To resist a compressive strain of 67,580 lbs. with a factor of safety of 10, the dimensions of a Memel fir beam should be $\frac{67,580 \times 10}{5,400} =$ 125 square inches, or about $11\frac{1}{4}$ inches square, say 12 inches square, or for the central beam, which is 15 inches wide, a nearly equivalent section 15 inches by 10 inches, and for the two side girders 10 inches by 8 inches.

It is next required to determine the dimensions of the straining beam B B′, the length of which is 12 feet. On the central beam the weight, acting at the head of the strut producing strain in the straining beam, is 13·5 tons, and the strain is this weight multiplied by the cotangent of the angle of inclination of the strut to the horizon

$$= \frac{A\,B \times 13{\cdot}5}{A\,C} = \frac{12 \times 13{\cdot}5}{6} = 27 \text{ tons or } 60{,}480 \text{ lbs.}$$

This strain of 60,480 lbs. is partly tension and partly compression under different conditions of loading, and inasmuch as timber is not able to resist so great a compressive strain as a tensile strain, the calculation of the dimensions of the beam will be for a compressive strain with a factor of safety of 10.

Dimensions of beam $= \frac{60,480 \times 10}{5400} = 113$ square inches, which is nearly equivalent to the dimensions of the struts; but, for the sake of symmetry, the straining beam and struts are similarly proportioned, viz., central straining beam 10 inches by 15 inches, and the side beams 10 inches by 8 inches.

The dimensions of the floor beams must again be determined, the distance between supports, that is to say the distance from centre to centre of the girders, is 5 feet, and inasmuch as the distance between the rails is 5 feet each floor beam will carry its maximum load at two intermediate points situated mid-way between each point of support.

The floor beams are spaced 3 feet $1\frac{1}{2}$ inches or 3·125 feet apart, and the total load on each floor beam = 3·125 × 2·15 tons, the maximum load per lineal foot = 7·03 tons. The portion to be borne by each half of the floor beam will thus be 3·51 tons or 7,862 lbs. The dimensions of a square Memel fir beam, 5 feet long between supports to carry a concentrated load of 7,862 lbs. with a factor of safety of 10, would be

$$\sqrt[3]{\frac{78,620 \times 5}{545}} = 8{\cdot}96 \text{ inches (say 9 inches).}$$

The dimensions adopted are 9 inches by 10 inches, the extra inch in depth being allowed for notching down the floor beams 1 inch on the main girders to give them extra rigidity. The only remaining calculation

is to determine whether the piles are sufficiently strong to carry their load, which on each pier will be 36 × 2·25 tons = 81 tons, carried in the proportions of 40·5 tons on the central pile, and 20·25 tons on each side pile. The dimensions of the piles are 14 inches square for the two outside piles, and 14 inches by 15 inches for the central pile, because it has to support the strut which has a width of 15 inches. The greatest unbraced length is 8 feet. Taking the central pile supporting the greatest load, then

$$BW = \frac{5{,}400 \times 14 \times 15}{1 \cdot 1 + \dfrac{8^2}{2 \cdot 9 \times 14^2}} = \frac{1{,}134{,}000}{1 \cdot 212}.$$

$= 935{,}643$ lbs. or 417 tons, and safe load $= \frac{1}{10} = 41 \cdot 7$ tons, as against 40·5 tons the actual load, which is a sufficiently close approximation.

The approximate quantities of materials in this bridge are as under :—

	£	s.	d.
1,992 cubic feet of timber, at 3s.	298	16	0
22¼ cwts. of bolts, nuts, washers, spikes, etc., at 12s. ...	13	10	0
6 pile-shoes, at 15s.	4	10	0
Total cost of timber work in bridge	316	16	0
Taking the effective span at 110 feet, the cost per foot run is	£2	17	7

The masonry abutments at each end have not been taken into account in this calculation, so that this omission would, to a considerable extent, be the cause of the difference in cost per foot run between this bridge and that illustrated in example No. 1.

Example No. 3.

The figures from 11 to 17 (Plates X. and XI.) illustrating the Soberg viaduct in Norway represent a system of timber-bridge construction introduced by Mr. Carl Pihl, engineer-in-chief to the Norwegian State railways, to whom the author is much indebted for a number of drawings and valuable information appertaining thereto. As will be seen by the drawings, these bridges, which are built of native timber in the rough state, are admirably trussed and very strongly put together. The various details are fully shown in the drawings, and it is unnecessary to supplement them with any descriptive particulars. It will therefore be expedient to proceed with the analysis of the strains, for which purpose the skeleton diagram given in Fig. 11 will serve.

Principles of Calculation.

In these trusses each span A A = A A″. Fig. 11 may be regarded as consisting of two sections A B and B A resting on their supports A B and A. It is therefore required first of all to proportion the girder A B A to the load it has to carry, in accordance with the preceding rules and examples.

Secondly, it is required to determine the stresses on the struts B C and B″ C″, for which purpose let S = the maximum strain, which in this instance will be compression, and let $W = W^1 = W^2 = W^3$ represent one-half of the total load on each span, then

$$S = \frac{B\,C \times \frac{W}{2}}{A\,C} = \frac{(\sqrt[2]{A\,C^2 + A\,B^2})\,\frac{W}{2}}{A\,C}.$$

The maximum strain on the tie C C which is tension

$$= S = \frac{W}{2} \times \frac{\frac{1}{2}\,C\,C}{A\,C}.$$

The maximum tension on the inclined tie C C″

$$= S = \frac{W}{2} \times \frac{\frac{1}{2}\,C\,C''}{A\,C}.$$

Having determined the value of these stresses, the various members can be proportioned, in the manner already explained, to the several loads which they have to carry.

The approximate quantities of materials in this bridge are :—

	£	s.	d.
2,012 cubic feet of timber, at 3s.	301	16	0
26 cwts. of iron, in bolts, nuts, spikes, at 12s. ...	15	12	0
26 pile-shoes, at 15s.	19	10	0
Total cost of bridge	£336	18	0
Cost per foot run	£3	7	4

Example No. 4.

The bridge illustrated in Figs. 18 to 25 (Plate XII.), is a trussed bridge, the principle of which was introduced in the year 1840 by William Howe, an American engineer, after whom it is called to this day the Howe truss. It is beyond a doubt about the best form of combining timber and iron in bridge construction that has ever been devised, and no better railway bridge can be built of timber, for spans up to 150 feet. It is a simple truss, consisting of chords, ties, and braces, the chords and braces being of timber and the vertical web-members or ties of iron.

The strain on the chords, resolving itself into compression on the upper chord and tension on the lower chord, is greatest at the centre of the span, and diminishes towards the ends. At the centre it equals $\frac{W\ L}{8\ D}$.

Here W = total weight of bridge and load.
L = length of span in feet.
D = depth of truss from centre to centre of chords.

The strains on the ties and braces, which always bear to each other at every point the proportion of the vertical height of the panel of the truss to the diagonal, is least at the centre, and it increases towards each end, where it attains a maximum, the strain on each end brace being equal to half the weight of the bridge and its load when uniformly loaded.

The counter-braces, when the bridge is uniformly loaded, bear no strain, and under other conditions of loading they perform a negative rather than a positive duty, since they are not capable of, nor designed for resisting tension. The duty they perform is this—when the bridge is fully loaded the counter braces are wedged up, the bridge is therefore constantly strained to the same extent as it would be under a maximum passing load, the effect of which would be instead of additionally instressing the various members to relieve them for the moment from the strain to which they are constantly subject. To provide for any deflection caused by the wedging up of the counter-braces, a camber is given to the truss, by making the lengths of the panel-tops slightly greater than the panel-bottoms.

The chords are made of two, three, or more sticks depending upon the magnitude of the span, secured together at intervals with bolts passing through distance blocks, leaving a clear space between the sticks to admit of the free circulation of air.

In the top chords bearing a compressive strain, each stick or member bears its due proportion of the strain, but in the bottom chord, which resists a tensile strain, provision must be made for splicing, so that if the chord consists of three members two only will be capable of resisting strain, and if the number of members is four then three only will resist the strain.

In the example selected, the height of the truss (20 feet), which, at a glance, as compared with the span, may appear out of proportion, has been adopted so as to enable the trusses to be laterally braced against wind pressure at a sufficient height to enable the locomotives and trains to pass underneath.

The span of the truss is 80 feet, the static or dead load is 0·6 ton, and the variable or live load 2 tons per linear foot. The strains on the truss are very simply determined, and written down in the manner shown hereunder. (Fig. 26, Plate XI.)

Calculation of Stresses.

Let n = number of panels = 8; panel length = 10 feet; span = 80 feet.

W = weight on one panel due to uniform or dead load = 6 tons.

W″ = weight on one panel due to variable or live load = 20 tons.

$ab = 10$ feet, $Bb = 20$ feet. $aB = \sqrt{ab^2 + Bb^2} = 22{\cdot}36$; $\frac{aB}{Bb} = 1{\cdot}118$.

Maximum compression on braces:—

$$aB = \left(3\tfrac{1}{2}\,W + \frac{28}{8}\,W''\right)\frac{aB}{Bb} = (21 + 70)\,1{\cdot}118 = \overset{\text{Tons.}}{101{\cdot}73} = \overset{\text{Lbs.}}{227{,}893.}$$

$$bC = \left(2\tfrac{1}{2}\,W + \frac{21}{8}\,W''\right)\frac{aB}{Bb} = (15 + 52\tfrac{1}{2})\,1{\cdot}118 = 75{\cdot}46 = 169{,}041.$$

$$cD = \left(1\tfrac{1}{2}\,W + \frac{15}{8}\,W''\right)\frac{aB}{Bb} = (9 + 37\tfrac{1}{2})\,1{\cdot}118 = 51{\cdot}98 = 116{,}450.$$

$$dE = \left(\tfrac{1}{2}\,W + \frac{10}{8}\,W''\right)\frac{aB}{Bb} = (3 + 25)\,1{\cdot}118 = 31{\cdot}30 = 70{,}120.$$

$$eD'' = \left(-\tfrac{1}{2}\,W + \frac{6}{8}\,W''\right)\frac{aB}{Bb} = (-3 + 15)\,1{\cdot}118 = 13{\cdot}41 = 30{,}050.$$

Maximum stresses on ties:—

$$Bb = \left(3\tfrac{1}{2}\,W + \frac{28}{8}\,W''\right) = (21 + 70) = 91{\cdot}00 = 203{,}840.$$

$$Cc = \left(2\tfrac{1}{2}\,W + \frac{21}{8}\,W''\right) = (15 + 52\tfrac{1}{2}) = 67{\cdot}50 = 151{,}200.$$

$$Dd = \left(1\tfrac{1}{2}\,W + \frac{15}{8}\,W''\right) = (9 + 37\tfrac{1}{2}) = 46{\cdot}50 = 104{,}160.$$

$$Ee = \left(\tfrac{1}{2}\,W + \frac{10}{8}\,W''\right) = (3 + 25) = 28{\cdot}00 = 62{,}720.$$

Maximum stresses on chords:—

$$ab = BC = 3\tfrac{1}{2}\,(W + W'')\,\frac{ab}{Bb} \;.\;.\;.\;.\;.\;.\;. = 45{\cdot}5 = 101{,}920.$$

$$bc = CD = 3\tfrac{1}{2} + 2\tfrac{1}{2}\,(W + W'')\,\frac{ab}{Bb} \;.\;.\;.\;. = 78{\cdot}0 = 174{,}720.$$

$$cd = DE = 3\tfrac{1}{2} + 2\tfrac{1}{2} + 1\tfrac{1}{2}\,(W + W'')\,\frac{ab}{Bb} \;.\;. = 97{\cdot}5 = 218{,}400.$$

$$de = \;.\;.\;.\; 3\tfrac{1}{2} + 2\tfrac{1}{2} + 1\tfrac{1}{2} + \tfrac{1}{2}\,(W + W'')\,\frac{ab}{Bb} = 104{\cdot}0 = 232{,}960.$$

In the top chords the strain is compression, and in the bottom chord tension.

Having thus determined the strains, it is expedient that they should be tabulated, so as to show at a glance the magnitude of the stress on each member of the truss, and the proportioning of that member to the stress it has to bear.

TABULATED STATEMENT SHOWING THE PROPORTIONING OF THE VARIOUS MEMBERS TO THE STRESSES BORNE BY THEM.

Particulars of Member Instressed.	Total Stress on Two Trusses.	Stress on One Truss.	No. of Members to Bear Stress.	Stress on each Member.	Theoretical Cross-section of each Member.	Actual Cross-section of each Member.	Dimensions of each Member.
Braces—	Lbs.	Lbs.		Lbs.	Ins.	Ins.	Ins. Ins.
a B	227,893	113,946	2	56,973	103·5	104	2 pieces 8 × 13
b C	169,041	84,520	2	42,260	77·0	80	2 „ 8 × 10
c D	116,450	58,225	2	29,112	55·0	64	2 „ 8 × 8
d E	70,120	35,060	2	17,530	32·0	48	2 „ 8 × 6
Counter brace—							
e D″ inches...	30,050	15,025	1	15,025	27·0	49	1 piece 7 × 7
Tie rods—							
B *b*	203,840	101,920	2	50,960	5·09	4·90	2 bolts 2½ dia.
C *c*	151,200	75,600	2	37,830	3·78	3·97	2 „ 2¼ „
D *d*	104,160	52,080	2	26,040	2·60	2·76	2 „ 1⅞ „
E *e*	62,720	31,360	2	15,680	1·56	1·76	2 „ 1½ „
Top chords—							Ins. Ins.
B C	101,920	50,960	3	16,987	31·0	72	3 pieces 12 × 6
C D	174,720	87,360	3	29,120	53·0	72	3 „ 12 × 6
D E	218,400	109,200	3	36,400	66·0	72	3 „ 12 × 6
Bottom chords—							
a b	101,920	50,960	2	25,480	25·4	72	3 „ 12 × 6
b c	174,720	87,360	2	43,680	43·6	72	3 „ 12 × 6
c d	218,400	109,200	2	54,600	54·6	72	3 „ 12 × 6
d e	232,960	116,480	2	58,240	58·2	72	3 „ 12 × 6

In the above tabulated statement the limit of strains is as hereunder, viz.:—

	Lbs. per Square Inch.
Timber in compression	550
Timber in tension	1,000
Wrought iron	10,000

Strain on Floor Beams.

The distance from centre to centre of floor beams is 6 feet, and the maximum load carried on this interval is 12 tons, supported at two intermediate points, that is to say 6 tons on each rail situated 2 feet 6 inches on each side of the centre of the span, which, between supports, is 13 feet. The equivalent centre load is therefore

$$\frac{6 \text{ tons} \times 4 \text{ feet} \times 2}{6{\cdot}5 \text{ feet}} = 7{\cdot}38 \text{ (say } 7\tfrac{1}{2} \text{ tons).}$$

A fir or Memel beam, 13 feet between supports, to carry a safe load of 7½ tons concentrated at the centre or a breaking weight of 75 tons or 168,000 lbs., should be of the following dimensions. Assuming the floor beams to be in two flitches bolted together, each flitch 9 inches wide, or the two together 18 inches wide.

Then the depth or

$$D^2 = \frac{168{,}000 \text{ lbs.} \times 13 \text{ feet}}{545 \times 18 \text{ inches}} = 222,\ D = 14{\cdot}89 \text{ inches (say 15 inches).}$$

The depth is thus 15 inches.

Track Stringers.

The greatest length of span unsupported between the floor-beams is 4·25 feet, and the maximum distributed load is 8·5 tons, which would be equivalent to a concentrated load of 4·25 tons, or 2·125 tons or 4,760 lbs. on each stringer.

The dimensions of a square beam, to carry a safe load of 4,760 lbs., or a breaking weight of 47,600 lbs., should be :—

$$\sqrt[3]{\frac{47600 \times 4{\cdot}25}{545}} = \sqrt[3]{371} = 7{\cdot}186 \text{ inches.}$$

The dimensions actually adopted are 9 inches.

Graphic Solution of Stresses.

The strains on the main truss can be very simply solved without the aid of any of the foregoing calculations, by graphic statics, in the following manner :—First construct a diagram of the truss to any scale, as shown in Fig. 26, then draw the line $a' a''$ in Fig. 27 parallel and equal to $a' a''$ in Fig. 26 (Plate XI.). From the centre X of the line $a\, a''$ in Fig. 27 let fall the perpendicular X Y, making it equal to $\frac{\text{W L}}{8 \text{ D}}$. Here W = the total weight of bridge and load, L the length of span, and D the depth of truss from centre to centre of chords. On the line $a' a''$, construct the parabolic curve $a\ y^3\ y^2\ y^1$ Y, etc., having its vertex at Y, then the abscissæ $x^3\ y^3$, $x^2\ y^2$, $x^1\ y^1$, X Y drawn in line coinciding with and prolonging the vertical lines B*b*, C*c*, D*d*, and E*e* in Fig. 26 will give the maximum strains in the chords.

To determine the strains in the web-members, from the point a'' lay off at right angles to the line $a''\ a$ the line a'' M, making the distance a'' M equal to the reaction at each abutment of the static load which equals one-half of the weight of the bridge, then join X M. Then the ordinates from the line $a''\ a$ to the line X M will represent at the various *loci* the magnitude of the strains due to the static or dead load.

Similarly, lay off from a'' in an opposite direction, the perpendicular a'' N, making a'' N equal to the reaction of the live or variable load, which would be one-half of the total live load. Then construct the parabolic curve N $o\ o^1\ o^2\ o^3\ o^4\ o^5\ o^6\ o^7$, etc., having its vertex above its base = a'' N. The complement of each ordinate drawn from o, o^1, o^2, o^3, o^4, o^5, o^6, o^7, etc., to the line $a\,a''$ will represent by scale the stresses on the vertical web-members B*b*, C*c*, D*d*, E*e*, etc., and the stresses on the braces will be in the proportion of the diagonal to the perpendicular, as shown in the left side of the diagram.

It may be observed that in graphic statics the larger the scale adopted for the diagrams the more closely can the stresses be evaluated.

The approximate quantities of materials in this bridge are as under :—

	£	s.	d.
1,898 cubic feet of timber, at 3s.	284	14	0
86 cwts. of bolts, nuts, etc., at 12s.	51	12	0
55 cwts. of cast iron in angle-blocks separators, etc., at 6s.	16	10	0
Total cost of bridge	£352	16	0
Cost per foot run, span being 80 feet ...	£4	8	2

Conclusions.

The conclusions to be derived, briefly stated, are, that for short spans up to 20 feet, where the height of the viaduct is not great, a bridge of the type illustrated in example No. 1 is the most suitable and economical, and for spans from 20 to 40 feet, with a moderate height, that illustrated in example No. 2 is a very good type of bridge. For viaducts of any considerable height it would be very difficult to design a better arrangement than that introduced by Mr. Carl Pihl, and illustrated in example No. 3. For bridges of spans ranging from 40 to 150 feet the Howe truss is beyond doubt the most efficient, simple and economical truss that can be adopted.

Mr. Edwin Gilpin, Jun.'s paper on "Explosions in Nova Scotian Coal-mines" was taken as read.

FEET.

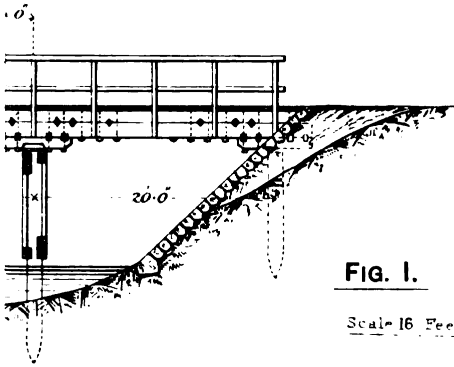
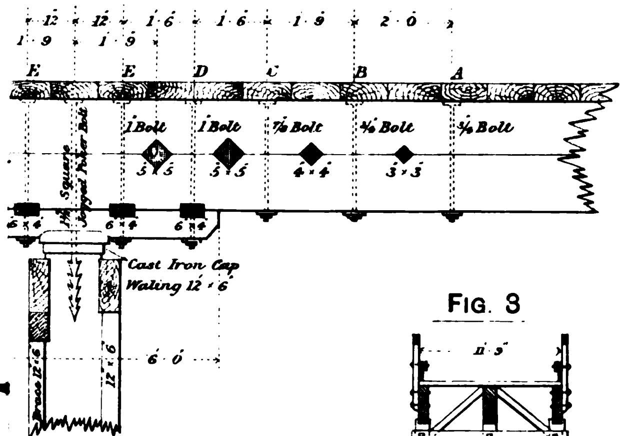


FIG. 1.

Scale 16 Feet to 1 Inch.

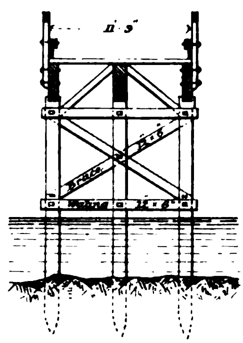
FIG. 5.



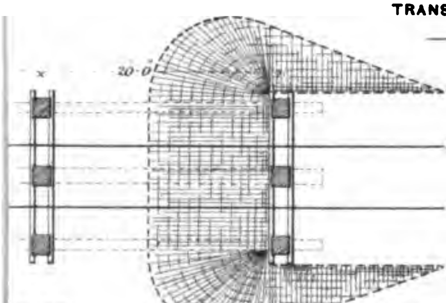
HEWING CORBEL
OGGLING OF BEAMS.

Scale 16 Feet to 1 Inch

FIG. 3



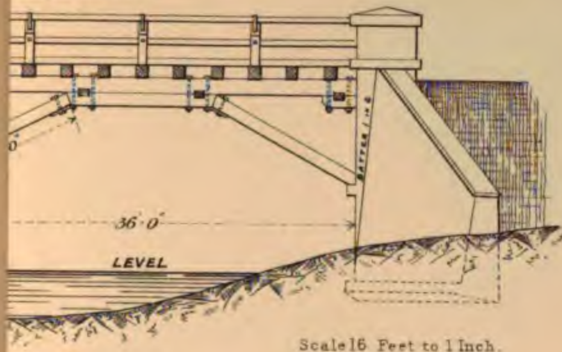
TRANSVERSE SECTION
AT PIER.



TIONS.

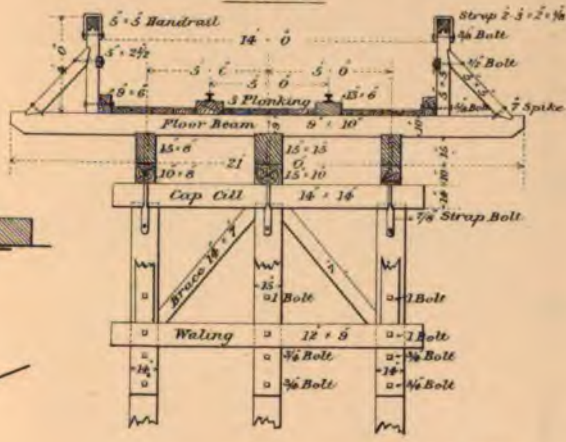
Scale 16 Feet to 1 Inch

6 FEET.



Scale 16 Feet to 1 Inch.

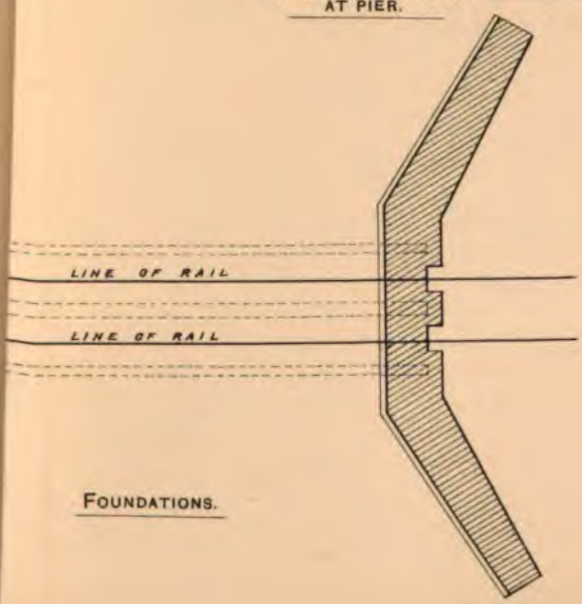
FIG. 9.



TRANSVERSE SECTION AT PIER.

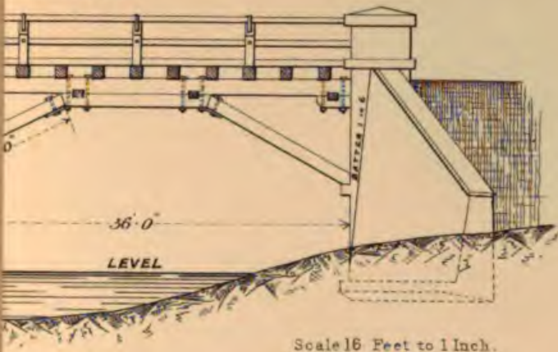
Scale 8 Feet to 1 Inch.

Scal



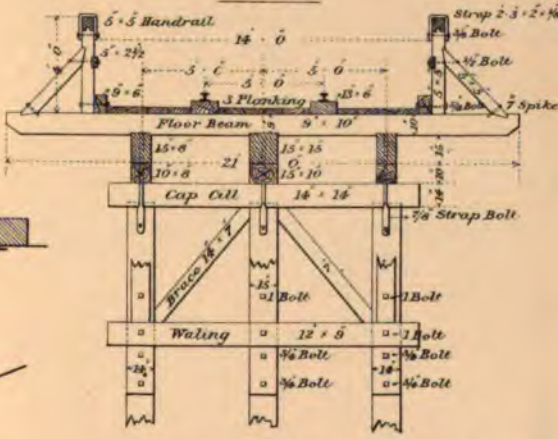
FOUNDATIONS.

6 FEET.



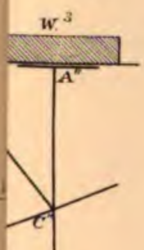
Scale 16 Feet to 1 Inch.

FIG. 9.

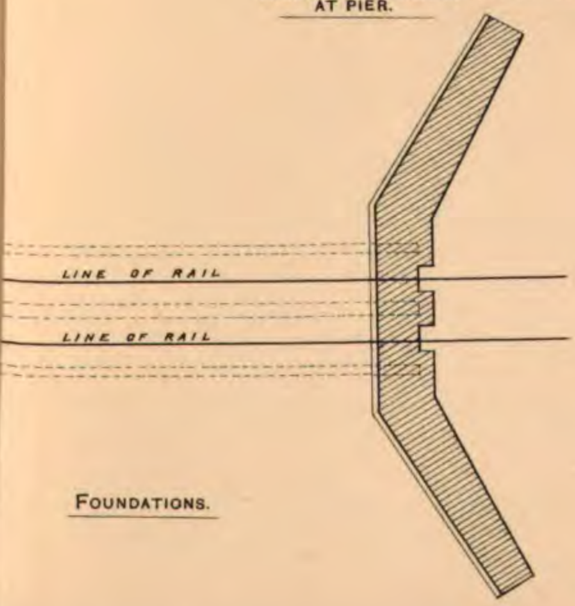


TRANSVERSE SECTION AT PIER.

Scale 8 Feet to 1 Inch.



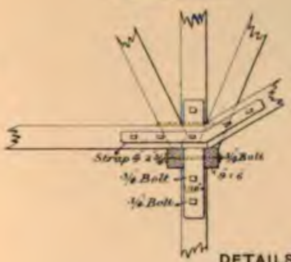
Scal

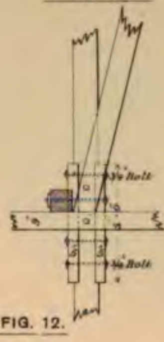


FOUNDATIONS.

FIG. 17.

FIG. 16.





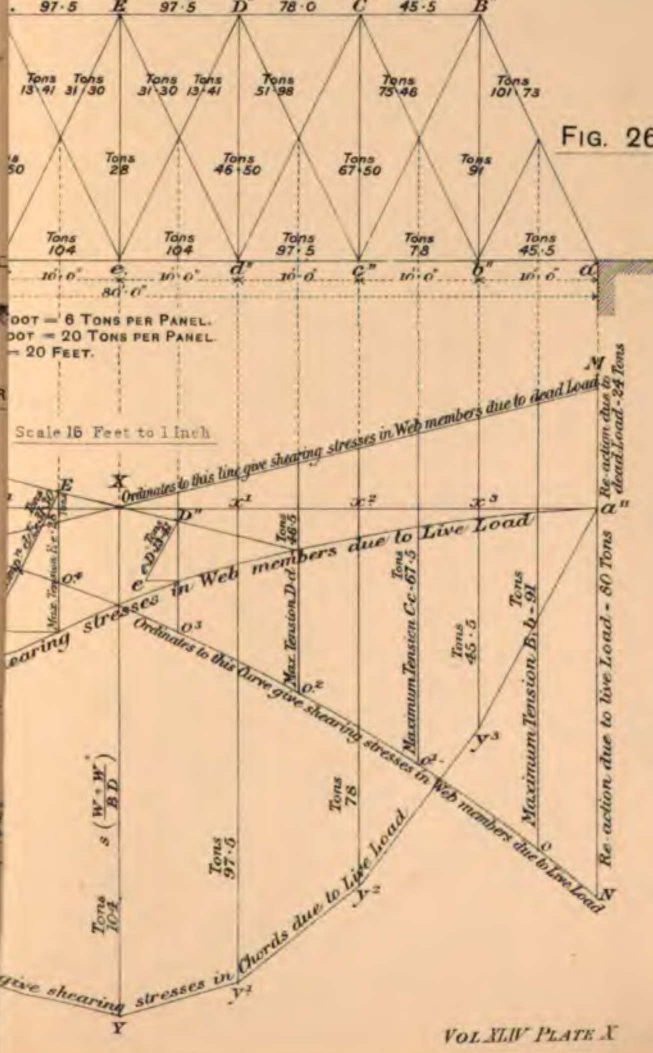
DETAILS AT C. FIG. 12.

Scale 8 Feet to 1 Inch.

NUED — GRAPHIC DIAGRAM OF STRESSES.

40 TONS TO AN INCH.

FIG. 26.



OOT = 6 TONS PER PANEL.
OOT = 20 TONS PER PANEL.
= 20 FEET.

Scale 16 Feet to 1 Inch

FIG. 17.

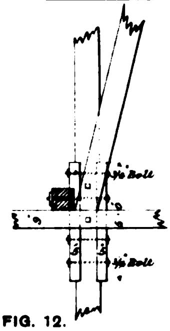
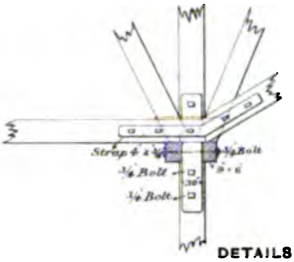


FIG. 16.



DETAILS AT C, FIG. 12.

Scale 8 Feet to 1 Inch

NUED — GRAPHIC DIAGRAM OF STRESSES.

40 TONS TO AN INCH.

FIG. 26.

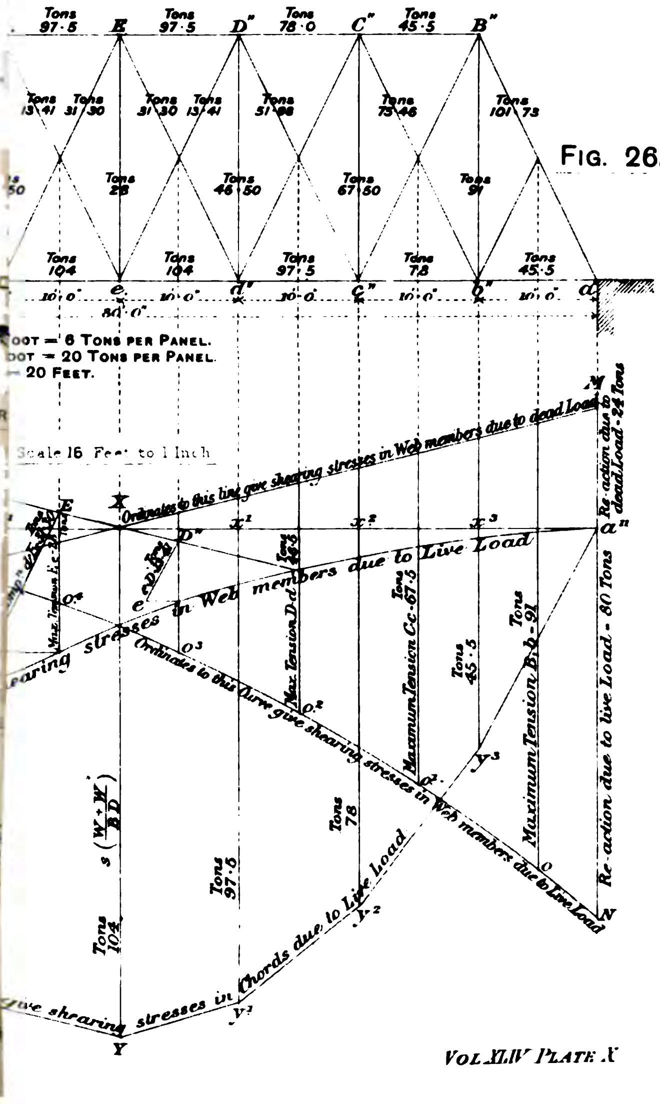
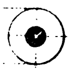


FIG. 23.

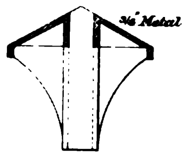
FIG. 24



SEPARATOR.

Scale 2 Feet to 1 Inch

FIG. 25.



ANGLE BLOCK.

SECTION THROUG
ABUTMENT.

Scale 16 Feet to 1 Inch

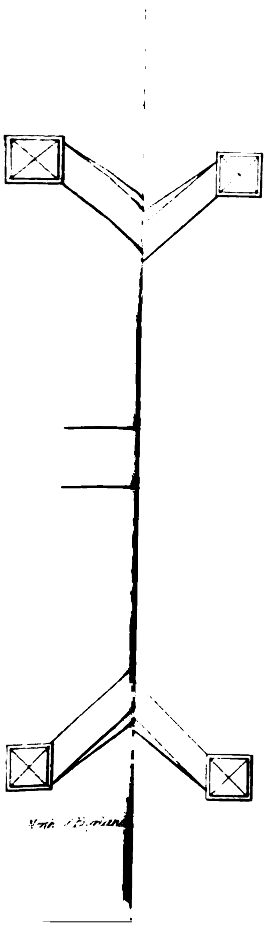
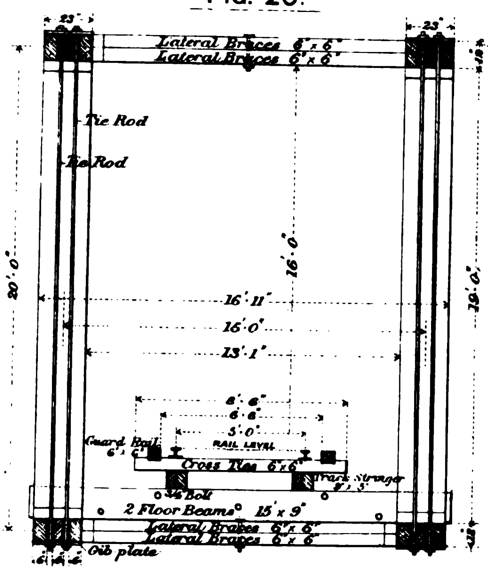


FIG. 20.



TRANSVERSE SECTION.

Scale 8 Feet to 1 Inch.

EXPLOSIONS IN NOVA SCOTIAN COAL-MINES.

BY EDWIN GILPIN, JUN., A.M., F.G.S., F.R.S.C., ETC., DEPUTY COMMISSIONER AND INSPECTOR OF MINES.

At present coal-mining is carried on in Nova Scotia in three widely separated districts. The geological horizon however of all is the same, the middle or productive division of the Carboniferous.

The coals from these districts vary somewhat in their general character. The Cape Breton seams are enclosed in strata holding many beds of sandstone with shales, arenaceous and argillaceous, presumably in large part formed from the re-worked beds of the adjoining Millstone Grit. The measures are usually presented at easy angles, and free from faults. In Pictou county the beds are thick, heavily inclined, frequently faulted, and at points associated with a great thickness of shale, carbonaceous, and occasionally somewhat bituminous. In a part of the Pictou district, to be more specially referred to later on, these shales attain a thickness of about 500 feet.

In the Cumberland district the natural sections of the Joggins present long-continued alternating deposition of shale and sandstone, with strata dipping at moderate angles, and not notably faulted. At Springhill, some 18 miles away, the same measures assume high angles, and are disturbed by heavy faults.

Broadly speaking, the Cape Breton coals are the most bituminous, followed by the Cumberland, and then by the Pictou coals. The coals of the two latter districts are rather of the free-burning type, although in some cases coking, but not as in the case of the Cape Breton coals almost invariably coking and adapted for gas-making.

The following average of analyses from a paper by the writer on Canadian coals will serve to show the differences in a general way:—

	Cape Breton.	Pictou.	Cumberland.
Moisture	0·75	1·19	1·46
Volatile combustible matter	37·26	29·10	33·69
Fixed carbon	58·74	60·63	59·35
Ash	3·25	9·34	5·50

The generally higher percentages of ash in the Pictou and Cumberland coals may be connected with the presence of the included beds of shale

already referred to, as compared with the small ash percentages of the Cape Breton coals associated with a larger proportion of sandstone-beds. The lesser thickness of the Cape Breton Coal-measures and the more bituminous nature of the coals may be contrasted with the free-burning characteristics of the western coals included in measures of much greater thickness.

The official records of coal-mining in Cape Breton go back to the year 1785. From that date to this the annual production has been comparatively small, amounting for the year 1893 in round numbers to 1,000,000 tons of coal. During this long period the deepest shaft and workings have equalled a vertical depth of about 700 feet. Gas has seldom been met in quantities large enough to cause trouble. One accident only requires record in this connexion. The mines iu this district were for many years damp along the outcrop workings, and can at this date be fairly called dusty in part of one mine only, attaining a vertical depth of about 700 feet.

The regularity of the seams, the overlying water-saturated sandstones, the thin cover, all, combined with changes of water-level effected by shafts, appear to have resulted in an almost complete discharge of gas from the seams as far as they have been worked.

There have been a number of cases of ignition of gas in Cape Breton, only one of which would be classed as an explosion, the remainder being of trifling extent due to small local collections of gas or to remissness in sweeping the workings thoroughly with the air. The explosion in question took place at the Sydney mines, on May 21st, 1878. The work of opening out the submarine operations was being pushed. From the pit-bottom an engine-plane ran to the north-east, and an engine-deep had been put down about 1,000 feet to the south-east to a landing. From this point a pair of levels had been driven southwardly for about 130 feet beyond a cross-cut which ran from the low level up through a few rooms that had been driven parallel to the levels. There was also a head between the levels within a few feet of the faces. It appears that a canvas door stood at the mouth of the upper of the two levels and forced the air-split for these deeps down the deep slant, along the low level, and then up along the working-faces. The places being idle, part of the canvas on the door was removed to another part of the pit, laying the two leve's dumb. After standing for several days, the place was entered by the upper level by the overman and a deputy carrying open lights, and a severe explosion ensued killing five men. The bodies of the over-

man and deputy were found about 60 feet from the face and not much burned. At this point the coal was not coked, nor were the props disturbed. In the lower level, however, there was evidence of great heat and violence; the explosion could be tracked out along the low level into the deep, where part continued across into the north deep workings and part towards the pit-bottom. When it is remembered that these levels from the south-east deeps were in only 130 feet beyond a cross-cut going to the rise and were connected by a head at their face, it is presumable that the management minimized the risk of gas accumulating. There was probably, judging from the position of the lamps and bodies, gas lying back to a distance of 60 feet from the face in both levels, and probably about 6,750 cubic feet of air containing gas as calculated by the manager, Mr. R. Brown. It would appear that the ignition of gas in the upper level flamed into the gas in the lower level, and, bearing dust and air with it, afforded an opportunity for the violence of the explosion. The workings are referred to by the inspector as dry, and the roadways as deep in dust. The management considered that although dry, the mine would not be considered as dry and dusty in a dangerous sense. This view would seem to be partly borne out by the fact that the coking of the coal and props did not extend for over 450 feet from the face of the low level. The management consider that, during the many years this seam has been worked, dust has played no part in any of the small explosions of gas which have occurred from time to time.

In Pictou county, the chief coal-mining interest centres around the main seam which lies at an angle of about 17 degs. and is bedded in the great mass of shales already referred to. The comparatively open character of the coal, lying in dry surroundings, and broken by numerous faults has made it a gas-drainage channel for a large area. This constant exudation of gas from the outcrop of the seam, some 40 feet in thickness, is reported to have been long known in Indian tradition, and at a distant date the ignition of the gas has caused a local fusion of a large body of shale overlying part of its outcrop. The word Pictou is stated to be the Indian equivalent for explosion, and may be connected with this fire. The gas exuding under the still water of the river crossing its outcrop could be ignited. Under these circumstances it will be seen that the operations in this seam begun in 1827 by miners accustomed to the thin seams of the North of England were attended with unusual difficulties. Little reliable information can now be secured as to the cause of the early explosions and fires in the Albion mines.

Systematic operations were commenced in 1827. On December 29th, 1832, fire was discovered in the pit, and it was found necessary to flood the workings. This fire was established to be of incendiary origin, but the guilty parties were never discovered. In 1834, the mine caught fire from a feeder ignited by a shot; in 1836, a heavy explosion killed several men; in 1838, during the sinking of No. 2 pit, an explosion killed three men. It may be remarked here that all shafts sunk in the great shale-bed overlying the main seam gave off gas.

Finally, in 1839, a feeder of gas lighted by a shot set fire to the coal and in spite of every effort the pit exploded with great violence during the night. So intense was the heat of the flames in the shaft that the hoisting-chains, etc., were melted. This first range of working was then abandoned.

Other shafts were then sunk to the dip. In 1862, night watchmen ignited gas and three men were killed. In 1867, these shafts were lost by a fire from an ignited feeder and filled with water.

In 1869, a new shaft called the Ford pit was sunk further to the dip, striking the coal at about 900 feet. As it was being holed around the shaft-pillar it caught fire and had to be flooded. This pit was re-won and successfully worked until 1880, when an explosion took place killing forty-four men, and it has remained practically closed since that date.

There is little information available about the earliest of these fires and explosions. Prior to 1869 the workings were damp, except in some of the working-places in the lowest deeps, as water followed the miners from the outcrop. The ventilation by furnaces with upcast shafts not exceeding 300 feet in depth was unable to sweep the huge chambers in this thick coal which were constantly accumulating gas. It is probable that the imperfections of the ventilation by allowing vitiated air to mix with the gas sensibly diminished its inflammability. It is stated that on one occasion the gas came off so strongly that on removing it by a heavy fall of water it fired at the boilers on the surface some 50 feet from the shaft.

The writer appends a copy of the special rules in force at these mines in the year 1840, which are of interest as showing a state of affairs in contrast to the practice of the present day and as showing that then, as now, the use of gunpowder was intimately connected with fire.

The Ford pit after a lifetime of about ten years was the scene of a violent explosion already referred to. In this case the side of the pit in which the explosion occurred had been reported as free from all but traces of gas at one or two points, up to an hour before the entry of the colliers (the testing was done with Clanny lamps, and the faces dated by the examiners).

The first explosion took place at 6 o'clock in the morning, and blew off the fan-drift cover. The rescue of bodies and the restoration of the ventilation were being successfully carried on when the presence of fire was detected, and shortly after a series of explosions rendered it necessary to close the shafts and seal the landings with water.

All attempts to account for the immediate cause of the explosion are necessarily conjectural, as all were lost who had entered the section that was the seat of the explosion, and the fire prevented a complete exploration after the first explosion. The chief points, however, that were observed by the exploring parties were that the flame of the explosion had not reached within several hundred feet of the shaft-bottom, that immense volumes of dust had been blown towards the shaft, and deposited on each side of the shaft. It appeared that the explosion had passed along a level to the dip of the wagon-road at the shaft-bottom, broken the back of the lamp-cabin, and had ignited coal-dust at the open light always kept there, killed the lamp-man, and showed traces of an explosion back to the shaft, or contrary to the direction whence the explosive wave had originally come. The shaft and approaches were all wet, and gas was unknown in its vicinity. At a distance of about 900 feet from the shaft-bottom the workings were dry and dusty. There appears to be little doubt that this explosion originated from a shot fired by the fireman shortly after the pit began to work ; that it was largely assisted by dust, that on arriving at the wet ground near the shaft bottom no signs of fire were visible on boards, canvas, etc., and that the finer particles of dust coming in contact with the open flame at the lamp-cabin about 100 feet from the shaft caused a slight secondary explosion.

The local nature of the explosion at the lamp-cabin was corroborated by the evidence of the wounded man, the position of the broken stoppings and the fact that the stables near the pit-bottom in the path of the first explosion showed no signs of flame. A short time ago the pit was pumped out and attempts made to reopen it, but outbreaks of spontaneous combustion in the old workings have led to a temporary cessation of the work.

This main seam is also worked about 3 miles to the westward by the Intercolonial Coal Co. Its character as regards gas is nearly the same as the similar workings in the Albion mines. On May 13th, 1873, a shot in one of the levels ignited a feeder.

The shot was in the bench or lower of the two slices by which the coal was mined. Owing to some want of care, the shot instead of

loosening the whole of the bench so that it could be readily removed, only broke the coal at the back of the bench next the face. Owing to the violent issue of burning gas through the mass of cracked coal it was found impossible to clear the bench away so as to get at the feeders. In a short time it was decided that the pit would have to be abandoned, but before all the men were got out a terrific explosion occurred causing the death of fifty-five persons. This explosion is believed to have been one of the most violent ever known in the history of coal-mining. After several days' work the openings were sealed. About two years later the mine was reopened, and has been working successfully since. The explosion presumably resulted from some body of gas being drawn upon the furnace fire from the rise-workings owing to a derangement of the ventilation, as several men who were in the workings near the point where the fire started escaped after the explosion. The pit was damp and not dusty.

Gas was given off very abundantly in this mine, and feeders of gas were daily ignited by the shots. In fact, no powder should have been used, but as there was at that time no Mines Regulation Act, it was impossible for the Government to enforce a prohibition in any way at variance with the practice common in other mines less gaseous. At present the improved mechanical ventilation, the use of safety-lamps and roburite have proved so far an effective safeguard, and the amount of gas evolved does not seem to have increased with the depth of the workings.

The main seam is underlain by the deep seam, being separated by 150 feet of shale. The seam is about 20 feet thick. Its character at the Albion mines has been decidedly less gassy than the overlying main seam. In 1858, there was an explosion of gas in the main levels which were in faulted ground. This explosion killed two men and wounded several others, and was entirely a gas explosion as the levels were making gas, and it was very wet out to the shaft-bottom. A similar lighter explosion occurred in 1864.

At the Intercolonial colliery during the latter part of the year 1892 a tunnel, 1,000 feet long, was driven from the 3,200 feet level in the main seam to cut the underlying or deep seam. The explosive used was roburite, and no difficulties were experienced until the lower part of the face of the tunnel struck the top of the seam when heavy feeders of gas were met. Two shotholes were fired in the rock preparatory to

entering the tunnel in the seam. The shots were fired together by electricity, a sharp explosion took place followed by the ignition of the feeders. The coal took fire, and after efforts were unsuccessfully made to put out the fire, dams were built, and work soon after resumed. Such enquiry as could be made showed that the shots were properly tamped, etc. It would appear that as the shots had not a solid backing of rock, they blew out and fired gas. The shot-firer had reported the place fit to fire shots in. The commission appointed some time before by the Government of Nova Scotia to enquire into the question of explosions reported that the precautions usually adopted in regard to testing for gas when gunpowder is used should not be omitted in the case of roburite or acadia flameless explosive (a local explosive possessing a high degree of safety). In this case considering that a large amount of gas was continually being evolved it would have been more in accordance with the spirit of the report of the commission not to have used any explosive. The instructive fact remains that roburite fired under apparently normal conditions ignited gas. The manager of the mine states that this explosive has been largely used by him and has given general satisfaction. In this connexion the deputy inspector for the Pictou district reports in the same year that flames had been seen by a number of parties from both these explosives.

It may be mentioned that the tunnel was dry, that the strata were composed of fireclay and blue shale, and that dust played no part in the explosions. After the face was recovered the seam was cross-cut, and as the drainage of gas was very heavy it was allowed to stand pending the drivage of a place downhill from the crop workings.

This seam was the seat of a very unusual explosion on August 8th, 1893. A small mine had been in operation for some years and dip works were being extended on the pitch of the seam to meet the tunnel—already referred to as the seat of an explosion caused by roburite. Owing to unusually dry weather the supply of water for the colliery boilers grew scanty. First, the working of the mine was abandoned, and then as the supply of water grew smaller, the steam was shut off the Schiele fan, and recourse had to natural ventilation. This was of course not counted on as effective as the seam was very gassy, but no danger was feared as the mine was closed and would not be entered again until the ventilation was restored. Naturally the mine filled with gas. On the day referred to, a heavy thunderstorm passed over the pit, a discharge of lightning injured several buildings close to the pit, and ignited the gas in the mine causing a heavy explosion. The discharge had presumably struck the iron pulley-wheels,

and followed the steel rope down to the cage which was standing about 20 feet from the bottom. The flash would occur at this point, and in an atmosphere almost undoubtedly filled with explosive gas. This accident, fortunately, accompanied by no loss of life, shows conclusively the effects of lightning, the pit being closed, and no person in the vicinity, and the explosion coinciding with a heavy lightning discharge.

The third seam underlying the deep seam about 85 feet was, on January 15th, 1888, the scene of a very violent explosion.

During the summer, part of the pillars in a panel in the third seam were drawn beneath the cage pit-workings at a point where a fire had been built off about the year 1872. This fire was believed to have been extinguished, and no danger was anticipated. After several pillars had been drawn the fall ran up to the cage pit-workings, hot stythe came into the third seam, and finally some of the stone that fell was found to be sensibly warm. The panel was built off at once, a work of no great difficulty, as there were only five openings. The temperature of the interior of the panel did not increase for several weeks, and it was believed that the fire would be extinguished. One Sunday morning, smoke was found in the returns, and shortly after a very violent explosion took place which destroyed the bankhead, and reduced tubs, brattice, etc., to matchwood. The side of the pit in which the explosion occurred was built off, and no further trouble has been experienced. The immediate origin of the fire is unknown. But the presence of smoke in the return before the explosion would make it appear probable that a fall or a slight explosion broke one of the stoppings, and that the furnace in the third seam drew gas from the upper seam upon the fire. Presumably the effect of the explosion was increased by dust, although the mine would not be classed as dry and dusty.

In the eastern part of the Pictou district the McBean seam is worked by the Vale colliery. On February 18th, 1885, an explosion occurred causing the death of thirteen men. It was claimed by the management that it was caused by dust alone from a blown-out shot. After a very careful enquiry it appeared most probable that it was due to a small body of gas and extended by dust. The writer quotes the report of the deputy inspector, Mr. Maddin, in whose charge the enquiry was placed.

The seam which dips at a heavy angle was opened by a slope which had been for some time working through the 1,800 feet levels, and was being sunk for a new lift. The sinking was down about 500 feet below the 1,800 feet level. While sinking, back slopes are driven on each side of

the main slope in the following manner :—Heads are driven right and left, at intervals of about 60 feet as far as the line of the proposed back slopes. The back slopes are formed by connecting the faces of theso heads by shoots or rises driven up hill from each head. It was known that these shoots when driven up off the air would gather gas. The air for the section of the mine in question entered by the main slope.

On the west side of this slope, at the 1,300 feet level, there were two check-doors which, when shut, sent the air direct to the dip, but when opened allowed most of the air to take a short cut to the fan. These doors were placed to allow the timber to be taken from the slope, and to be carried to the head of the shoots to be lowered to the working-places in the level below.

Men were engaged in this work at the time of the explosion, and it is believed that some derangement of the ventilation at this point allowed gas to accumulate in a head in the sinking, in which a miner named Foley was working about 100 feet from the face of the sinking; and that the restoration of the air-current, which was strong and sharp, forced the gas upon Foley's lamp. He was burned to a crisp, while the men nearer the face were almost untouched by fire. The timbers in the slopes from the head in which Foley worked down to the face of the sinking gave unmistakable evidence that the explosion came from above, while the timber up the slopes from Foley's head for 400 feet to the 1,800 feet level gave like evidence that the explosion came from below. At the 1,800 feet levels the check-doors were destroyed, and signs of the explosion found for about 400 feet from the slope. The stoppings all along the slope were blown out, and the slope badly wrecked, but at no point did the explosion extend over a few hundred feet to the right and left of the slope. The floor of the main slope in the sinking was damp, but there was much dust on the timbers in the slope, and the coal gave off a good deal of dust under a vertical pressure of about 1,200 feet. The explosion found the mine at the height of the winter in its driest condition. When the water which had gathered at the face of the sinking was removed a shothole was found. A very careful examination into the matter failed to produce any evidence that the hole had been charged. The explosion had followed the line of least resistance, viz., directly up the slope to the open air, and resembled one at the bottom of a shaft.

In the absence of the explanation afforded by the fact that on previous occasions the accidental neglect in shutting the doors on the 1,300 feet level had caused an accumulation of gas in the sinking, and by the fact that at the time of the explosion the doors in question were more or less open, it might have been reasonably urged that it was a dust explosion.

On February 21st, 1891, an explosion accompanied by heavy loss of life took place at the Springhill mines, Cumberland county. At this point three seams are worked by three slopes : all the workings had been connected by tunnels, but those leading into the north seam had fortunately been built off before the explosion. The seams dip at an angle of about 27 degs., and are opened by slopes, with levels at convenient distances apart. From the levels places are driven to the rise on the full pitch of the seam, and horizontal bords turned away. The tubs are raised and lowered, between the bord-mouths and the level, on platforms worked by counterbalances.

The seat of the explosion was in the No. 6 and No. 7 balances of the 1,900 feet west level of the east slope, at the face of the working of this section. These balances, about 600 feet in length, extend on the full pitch of the seam from the 1,900 to the 1,300 feet levels, and take the coal from the usual horizontal bords or working-places.

These balances were connected with the 1,300 or stony-level, and were ventilated by air from the lower level, which was divided between the balances and uniting at the 1,300 feet level ventilated the workings above that level, and passed to its outlet beyond the faces of the workings above the 800 feet level. The air was provided by a downcast fan, and appeared to be ample for the extent of workings. Repeated examinations appeared to indicate that the explosion started from a point about the centre of No. 7 balance (the furthest in balance) and to have gone up and down the balance, wrecking the working-places branching off from it. Also to have penetrated into No. 6 balance through the lower working-places in it, which had been worked through into No. 7 balance, and in a similar manner to have wrecked that and the working-places branching off from it. As the connexions between the top of the balance and the 1,300 feet level were comparatively small, the force of the explosion extended but a few feet through them into that level. The openings into the 1,900 feet level being larger, the explosion was felt severely at the foot of the balances, and the two levels were wrecked into their faces a distance of about 400 feet, and towards the slope for a distance of about 1,500 feet. The force of the explosion was slightly felt at the bottom of the slope, and did not attract attention at the surface, except by a momentary agitation of the fan at the east slope and a slight puff of air at the west slope in the underlying seam, which was connected by a tunnel with the east slope seam, a few feet from the top of the No. 6 and 7 balances. The explosion ignited some canvas-brattice and boards in No. 6 balance, but this fire was extinguished without difficulty.

The workings of the No. 7 balance were naturally very dusty, and were systematically watered, an ample supply of water being led through them by pipes from a large pump standage or lodgment on the upper level. The water that made on the 1,300 feet level was used for watering No. 6 and 7 balances. The watering was effected by putting a valve on the pipe in each working-place in No. 7 balance, so that a coal-box, holding a barrel, could be run under it and filled, and the orders were that it should be thrown on the roof and sides of the working-places. Water was also allowed to run into the bords, and the shot-firers were instructed to see that the vicinity of the shot to be fired was damp. The amount of water available, and the directions for its use, should, in the writer's opinion, have kept the stationary dust well damped.

The reports show that the workings in No. 7 balance were free from gas on the morning of the explosion, and the available evidence points to the fact that there was no lying gas up to the time of the explosion, as the brattice-men who had completed their special work in other parts of the slope were killed by the explosion in the lowest bord of the balance on their regular rounds for the purpose of testing stoppings, brattice, etc. Evidence was given to show that the levels had been making gas for some time, but the ventilation was good, and no accumulations were permitted.

From the evidence produced, the directions to the shot-firers, night-men, brattice-men, etc., were adequate, and properly carried out. There appeared in some instances to have been latitude allowed by shot-firers to miners in respect to charging holes before they were examined. In the writer's opinion, when the supervision of shot-firers is considered necessary, no hole should be charged before it is measured by the shot-firer and the amount of powder used should be subject to his opinion. The writer is the more inclined to this opinion in reviewing this matter, as the evidence tended to show that the "flaming" shots referred to in the investigations were in some instances contributed to by a want of attention in placing the hole and the charges of powder.

In the No. 7 balance locked lamps were used, except by the cage-runner in the counterbalance, who was allowed to use an open light. The author does not know that this in any way contributed to the explosion, but it may be conceived that in the case of an explosion driving before it and beyond its own sphere of ignition, a mixture of dust and gas, an open light might be instrumental in starting a second explosion. It is further to be remarked that the men employed, who are furnished with locked lamps, are naturally inclined to be sceptical as to their value if they know that within a short distance open lights are permitted.

From the evidence taken it appeared that the manager, Mr. Swift, who was killed by the explosion, his assistant, the underground managers, and other officials were careful and attentive, and that daily reports and check reports were used.

In the No. 7 balance, when the bords were first started, the coal was worked to its full height, having a bench of about 4 feet, then a stone band, and above that about 3 feet of coal. After the bords were driven in a short distance, the fall coal and stone were left in and the bench only was worked. This coal was not worked with powder, but as the face advanced it was necessary to blow down from 12 to 18 inches of the stone, to make room for the tubs to get near enough to the face to permit of their being loaded with coal. The stone was blown down in the low side of the bords, over the rails, and stowed in the high side. A row of props along the middle of the bords held the rest of the stone up. There was consequently little shot-firing done in the balance workings. The stone is about 2 feet thick, a coarse sandstone, with streaks of coal sometimes 2 inches thick. It was shown in evidence that usually the holes for the shots in the stone were bored in the coal streaks and were in some cases partly in stone and partly in coal.

It was shown that on the day of the explosion a shot was to be fired in this stone in the No. 3 bord in No. 7 balance, and that Thos. Wilson, the shot-firer, left the bottom of the slope about a quarter past twelve o'clock, saying he had to go to No. 7 balance. The explosion occurred shortly before one o'clock, a time having elapsed, in the opinion of the witnesses, sufficient to have allowed him to reach this point, to have made the necessary preparations, and to have fired the shot. His body was found, with those of the men working in the bord, near the entrance to the place. The shot in the stone had been fired. This, coupled with the direction of the course of the explosion, showed with reasonable certainty that it had its origin in the bord, and that the shot fired by Wilson was the direct cause of the explosion.

The suggestion was made by Mr. Madden, the deputy inspector, who was at hand at the time of the explosion, and rendered valuable aid to the rescuing and exploring parties, that the immediate seat of the explosion was to be sought in the stone itself. After examining the bords in question with him, the writer is of opinion that his suggestion offers the readiest explanation as to the source of the catastrophe.

The bord is 14 feet wide, and the stone is carried by a row of props in the middle. These props were set by the miners as they advanced the face, to hold the stone, which was not of a specially strong character, con-

sequently, as the stone was not blown down until it became troublesome to move the tubs, there were always props along the side of the shots, and between the shots and the face. The effect of these props was to partly confine the shots to the low side of the bord.

As the stone was in layers, and had streaks of coal in it, examination showed that it was more or less fissured across the bord, and hung on the props, the natural effect of the shots being to blow in along the layers, to compress the props, and to cause the stone to bag between the props and the high side. That this effect was produced is shown by the fact that large quantities of this stone fell in the workings of No. 7 balance, the props being knocked out by the explosion although very short, and partly supported by the stone stowed in the high side. The hole that was fired in No. 3 bord, was, so far as could be estimated, from 2 feet 9 inches to 3 feet long. The end of the hole was in stone. The charge of powder appeared to have filled 18 inches of the hole. The shot threw down about three-fourths of the stone it was designed to dislodge, and left the balance split by the heel of the shot, and a prop near the back of the hole. There was a lype in the stone on the low side of the bord, which may have helped to lessen the desired effect of the shot.

The weight of evidence appeared to be that there had been an overcharge of powder.

It would appear that the expansion of the layers of the stone afforded space for the accumulation of gas, which would not be readily dislodged by the air-current, and an unusual opportunity of accumulation, owing to the fact that the pit was idle the preceding day. That the shot gave evidence of having been a more or less flaming one; that it ignited the gas lodged in the roof stone; that this combination of gas and powder flame acting on an atmosphere charged with a small percentage of gas and fine floating dust derived from the lower bords, caused an intense flame sufficient to propagate itself until it reached an intensely explosive state and self-supporting, swept the two balances and the adjacent levels.

The general opinion of the witnesses was that the shot-firer was a careful man, and there is evidence that the explosion was not like that of a body of gas. Men working in the lower seam under the seat of the explosion, and separated by a few feet of measures, stated that as usual, they heard a shot fired above them. Then after an interval of a few seconds it was followed by a series of detonations which appeared to shake the roof over their heads. The face of No. 3 bord inside the shot was found to be free from dust and sign of fire. The explosion broke

only a few coal tubs, and did not do much more than dislodge the props. Almost immediately after the explosion men were able to go straight into the faces of the levels, past No. 6 and 7 balances. Their lamps burned well, although they were themselves affected. These facts point, in the writer's opinion, rather to the comparatively slow progress of a dust-supported explosion than to the sudden clap of an ignited inflammable body of gas and air.

The evidence of Enoch Cox, who worked in No. 1 bord, on the same balance, supports this view. He testified that some time previous to the explosion a shot was fired in this stone that filled his working-place with flame, and ignited the gas in the stone, so that it required some effort to extinguish it. It is fair to state that the management declare they never heard of this, and that it was never reported to them.

The mine had been carefully examined on the previous day by the deputy inspector, and two days before a committee of the men had examined this mine and were quite satisfied with the ventilation and the precautions taken to keep the workings damp.

These notes give a brief account of the principal explosions that have occurred in our coal-mines. The writer has a personal knowledge of all the mines, and has been able to enquire personally into the facts connected with most of them. So far his experience has been that no explosion in Nova Scotia can be attributed to coal-dust alone, but a number of them have had their area and their destructiveness to life materially increased by coal-dust.

Special Rules in force in Pictou Co. fifty-four years ago (1840).

Instructions.

Rule 1.—The overman, and at least one of his deputies or assistants, shall examine all the bords and other working-places every morning before the colliers go down. They shall meet the colliers and other workmen at the bottom of the shaft, and if they have found any gas or other cause of danger in any of the bords, shall caution the colliers belonging to such bords and give them such instructions as they deem necessary.

Rule 2.—Whilst the pit is at work an overman or deputy shall always be present at each face of the works, viz., one on the north and one on the south side, so that in case of an alarm of fire or any other accident the overman or deputy shall always be at hand or within call.

Rule 3.—When the day's work is finished the overman or his deputies shall remain in the mines for the purpose of going through every bord and carefully examining them after the colliers have left, so that no blower or gas may be left burning, or any fire concealed amongst the fallen coal.

Rule 4.—Every bord shall be furnished with a fire-bucket marked with the number of the bord, a coarse bag for beating out gas, and a tub or open-headed cask to contain 40 or 50 gallons of water. The fire-bucket and the bag shall be in charge of the colliers of each bord, who shall pay for or replace them if lost.

Rule 5.—Every panel, consisting of six bords, shall be furnished with a small cannon, which shall be kept at some convenient spot in the lowest board. The overman and deputies shall keep the cannon clean and dry and ready for use. They shall also keep the tubs constantly full of water in each bord.

Rule 6.—Every bord shall at all times be furnished with a safety-lamp, which shall be examined by the overman at least twice a week, and in case of any injury being done thereto, more than common wear, the cost of the lamp shall be charged to the colliers, in whose care it is placed.

Rule 7.—Any collier meeting with a cutter or fissure which yields gas, or with anything unusual in his bord, shall immediately report the same to the overman or deputy.

Rule 8.—No collier shall be allowed to put in more than one shot or blast at a time, into any bench or fall, without permission from the overman.

Rule 9.—After blasting either a fall or bench, the coal shall be turned back, so that no fire may be concealed amongst the loose coal, and before the colliers leave their bords they shall be careful that no blowers or gas are left burning.

Rule 10.—No collier shall work in any fiery bord unless there are other colliers working in the adjoining bords at the same time.

Rule 11.—The coal shall not be blasted or a naked light used on any pretence whatever in any bord or working-place in which the overman has forbidden gunpowder or naked lights to be used.

Rule 12.—Every person employed in the pits on passing through any air-door or trap-door shall always close it after him.

Rule 13.—No person shall unscrew his safety-lamp (where such are used) excepting when and where he is ordered or directed to do so by the overman or his deputy.

Rule 14.—When a blower or body of gas is fired by a shot or otherwise, which cannot be at once extinguished by the ordinary means, notice shall be sent without delay to the overman or deputy; and in the meantime the colliers from the adjoining bords shall be called in to give assistance.

Rule 15.—On the arrival of an overman or deputy at the fire, all the colliers and other persons who may be present or sent for shall act under his orders, and use every exertion to carry them into effect.

Rule 16.—The extinguishing-engine shall be kept in a proper house near the pit-top, and a bell of not less than 28 lbs. weight shall be hung upon the pit-frames at No. 1 shaft, with a rope leading to the bottom of the shaft, for the purpose of making signals from below without loss of time.

Rule 17.—The overman or deputy on his arrival at a fire shall, if he considers it necessary, cause the bell to be rung for the extinguishing-engine, and to give notice to the manager, or deputies, or other persons who may be on the surface, whose duty it is to be present, that they may immediately go down.

Rule 18.—In all cases of fire a most determined effort must be made with the extinguishing-engine; beyond this it is impossible to frame any rules that will apply generally. The manager and his assistants must then decide what further measures to adopt.

Rule 19.—The overman or the deputies who shall have gone through all the bords after the workmen have left the mine shall report personally to the manager, the general state of the works, and particularly whether the cannon, buckets, water

tubs, etc., are all in readiness for any emergency, and in case the manager shall be absent they shall enter their report in writing in a book kept in the office for that purpose.

Rule 20.—No deputy shall at any time whilst on duty in the pits, during working hours, leave his appointed station until relieved by another deputy, to whom he shall report the state of the works under his charge, together with any instructions he may have received from the overman.

Rule 21.—At all times, whether there is any apparent danger or not, the foregoing rules shall be strictly adhered to, without the slightest relaxation, their object being to protect the lives of the workmen, as well as the works themselves; and any person neglecting, or in any way evading them, shall, if the manager thinks proper, be dismissed from the service.

The PRESIDENT said that Nova Scotia appeared to have suffered severely from explosions. Some of the mines appeared to be very gassy and also to contain dangerous dust, but Mr. Gilpin did not attribute any of the explosions to coal-dust alone. Blasting with gunpowder seemed to have been the most frequent cause of ignition, and in one case feeders of gas were ignited by roburite. The report of the Royal Commission on Explosions from Coal-dust in Mines had focussed opinion on the subject, and their recommendations involved further legislation, which it was important should be based upon facts—so as to secure a maximum of safety without placing unnecessary hindrances or restrictions upon the mining industry. The experiments of the Explosives Committee of the North of England Institute of Mining and Mechanical Engineers were likely to throw much light on the relative safety of the various new explosives. The first report of this committee was now in the press and would shortly be published in a form obtainable by all members of The Federated Institution of Mining Engineers. The explosion attributed by Mr. Gilpin to roburite appeared to have been caused by the ignition of gas when a seam of coal was cut into by a stone-drift. This was a very interesting explosion if it were clearly established, as it appeared to be by the account, that it was actually due to roburite fired by electric fuze.

Mr. H. BIGG-WITHER wrote that the circumstance mentioned in Mr. Gilpin's paper was reported to him, and, as far as he could recollect, he was informed that the shots were fired in very broken strata which was full of gas. The conclusion he came to at the time was that the shots were placed in holes where there was actually gas, so that to all intents and purposes they were untamped shots. He might mention that the roburite used was manufactured in Canada from ingredients supplied by the Roburite Company.

Mr. E. Gilpin, Jun., wrote that in Nova Scotia they had not yet grappled directly with the dust problem, preferring at present to seek safety in exclusion, as far as possible, of explosives. All the dusty mines are gassy, and in most no explosives are used. Roburite was undoubtedly the cause of the explosion referred to as occurring when a coal-seam was cut by a stone-drift. A full account of this explosion and subsequent extinguishment of the fire has been written by Mr. C. Fergie, the manager of the colliery.* The writer encloses a copy of the Mining Regulations of Nova Scotia bearing on the use of explosives:

(8.) Any explosive shall only be used in the mine underground as follows:—

(*a.*) It shall not be stored in the mine.

(*b.*) It shall not be taken into the mine, except in a case or canister containing not more than six pounds.

(*c.*) A workman shall not have in use at one time in any one place more than one of any such cases or canisters.

(*d.*) It shall not be taken into or be in the possession of any person in any mine or district of a mine, and shall not be used except in accordance with the following regulations, during two months after any inflammable gas in quantity sufficient to show in a safety-lamp has been found in three consecutive days in any such mine; namely:—

(1.) Either in those cases of stone-work or sinking of shafts in which the ventilation is so managed that the return air from the place where the explosive is used passes into the main return air-course without passing any place in actual course of working; or

(2.) When the persons ordinarily employed in the mine are out of the mine or out of the part of the mine where it is used.

(3.) Where a mine is divided into separate districts in such manner that each district has an independent intake and return air-way from the main air-course, and the main return air-course, the provisions of this rule with respect to explosives shall apply to each such district in like manner as if it were a separate mine.

(*e.*) A competent person or persons shall be employed for the purpose of firing all shots during three months after any inflammable gas has been found in any such mine or district of a mine, or under the provisions of sub-section (*d*). He shall, before firing any shot, carefully examine the place where it is to be fired and the places adjoining. A shot shall not be fired after the first of January, 1892, except by or under the direction of a competent person appointed for the purpose and holding an underground manager's, overman's, or shot-firer's certificate.

Provided, however, if at any time the inspector of mines, together with any persons experienced in the composition or use of explosives, who he may associate with himself for the purpose, shall report that any explosive is free from danger, the Lieutenant-Governor may, by Order in Council, determine that the restrictions of sub-section (*d*) of this section shall not apply to such explosive, and in such cases such explosive may be used so long as said Order in Council remains in force.

The Commissioner may, upon representation made to him in writing by the owner, agent, or manager of any mine, that the finding of inflammable gas in three

* *Transactions of the Nova Scotia Mining Society*, vol. i., part 4, page 44.

consecutive days, alluded to in this rule, in any such mine is exceptional, and that the mine is damp, and not dry and dusty, cause an examination to be made of such mine by the inspector, and may order that the use of any explosive is obligatory under this rule only if inflammable gas is found in two consecutive days on any two consecutive weeks.

Up to the present time these special rules have been found to lead to increased attention to ventilation, etc.

The PRESIDENT then said that he had pleasure in moving a vote of thanks to Mr. Gilpin for his interesting paper.

The vote was unanimously agreed to.

The following paper by Mr. Joseph R. Wilson on "The Shaw Gas-tester for Detecting the Presence and Percentage of Fire-damp and Choke-damp in Coal-mines," etc., was then read :—

THE SHAW GAS-TESTER FOR DETECTING THE PRESENCE AND PERCENTAGE OF FIRE-DAMP AND CHOKE-DAMP IN COAL-MINES, ETC.

By JOSEPH R. WILSON, of Philadelphia, U.S.A., Member of the American Institute of Mining Engineers, etc.

During the last seventy years numerous experiments have been made in devices for the detection of the presence and percentage of explosive gas in coal-mines, commencing with the Davy lamp, which in principle and construction sufficiently resembles the safety-lamps of to-day to be correctly regarded as the prototype, whose individuality is distinctly impressed upon all subsequent inventions of this character, the distinctly fundamental principle, which so far as safety-lamps are concerned has never been departed from.

The ability of the Shaw instrument covers such a large field that it will be in order to state first what it will do, followed by its construction, and ending with its operation. Four years of careful study and daily use of the appliance enables the writer to treat the subject from each standpoint.

The first question that one would naturally ask is, what is the Shaw gas-tester? The answer, though lengthy, would be as follows:—

It is a mechanical device that can be used by the unskilled for the rapid estimation of the amount of fire-damp and choke-damp in the air of coal-mines. The results obtained being absolutely accurate to the 0·001 part.

The writer will now describe the device as shown in Fig. 1. To be brief, the apparatus is made of brass and iron, is about 2 feet square, and weighs 90 lbs. It consists of a pair of pumps A and B; one (A) takes in air, the other (B) takes in pure gas as a base to measure from. The air-cylinder is stationary, and the stroke of the piston is always constant. The gas-cylinder (B) is movable, and can be set between two graduated bars so that it will pump 1, 2, 3, 5, or any desired percentage of gas in conjunction with air from the air-cylinder, the sum of the two

always equalling 100 parts, so that if 2 per cent. of gas is taken in the gas-cylinder, 98 per cent. of air would be taken in the air-cylinder; and if 20 per cent of gas, there would be 80 per cent. of air and so on, the calculation on the graduated beam on which the gas-cylinder operates having been made in a curve, so that the sum of the two cylinders shall always equal 100 parts, instead of 100 of air and 2 of gas, or 100 of air and 10 of gas, the product is 98 per cent. of air and 2 of gas, and 90 of air and 10 of gas. The pistons are operated by a hand-crank (N) acting on the graduated arm or lever that regulates the stroke of the piston in the gas-cylinder, and the product of the two cylinders is pumped through an ejector or mixer (not shown) into an igniting chamber (Z), which has an aperture on one side in front of a gas-jet. Should the mixture pumped into the chamber be inflammable, ignition will take place, and the expansion caused by the heat will propel a loose piston-head, held in place by a bowstring, at the end of the chamber against a gong, producing an audible sound. The addition or subtraction of 0·1 per cent. will cause this gong to ring or remain silent; in other words, this apparatus will determine the igniting-line of gases which lies within the narrow limits of the 0·001 part, and which is as fine as the line between oil and water in a test-tube. The test for inflammable gas is made on this basis, the igniting-line. Philadelphia illuminating gas rings the gong at 8·1 per cent of gas and 91·9 of air, though this will vary in the manufacture; 8 per cent. of this gas will not ring the gong, the addition of 0·1 per cent. being necessary. This is what is called finding the standard, or base-line to measure from, which varies with the kind of gas used. Natural gas will give a standard from 4 to 6 per cent., while manufactured gas may be anywhere from 7 to 9 per cent. This difference does not alter the condition of test, as the igniting-line can be ascertained, whether it be at 4 or 9 per cent.

The air in the mines to be tested is captured by means of a diaphragm hand-pump and a 6 gallons rubber bag. The diaphragm pump is light and easily handled. The vibration of the diaphragm throws about 1 pint of air each stroke. The air is drawn in a tube ½ inch in diameter, and forced into the bag. When filled the bag is held by the hand, in close contact with the neck, and pulled off the pump, and an ordinary paraffined cork inserted to retain the captured air. When the bags are filled small paper tags are attached to note the time of day and place where the air was captured, and the bags brought either outside or to the foot of the intake, where they are attached to the instrument, and the contents made known as follows:—

To test for fire-damp, a bag of pure carburetted hydrogen, captured

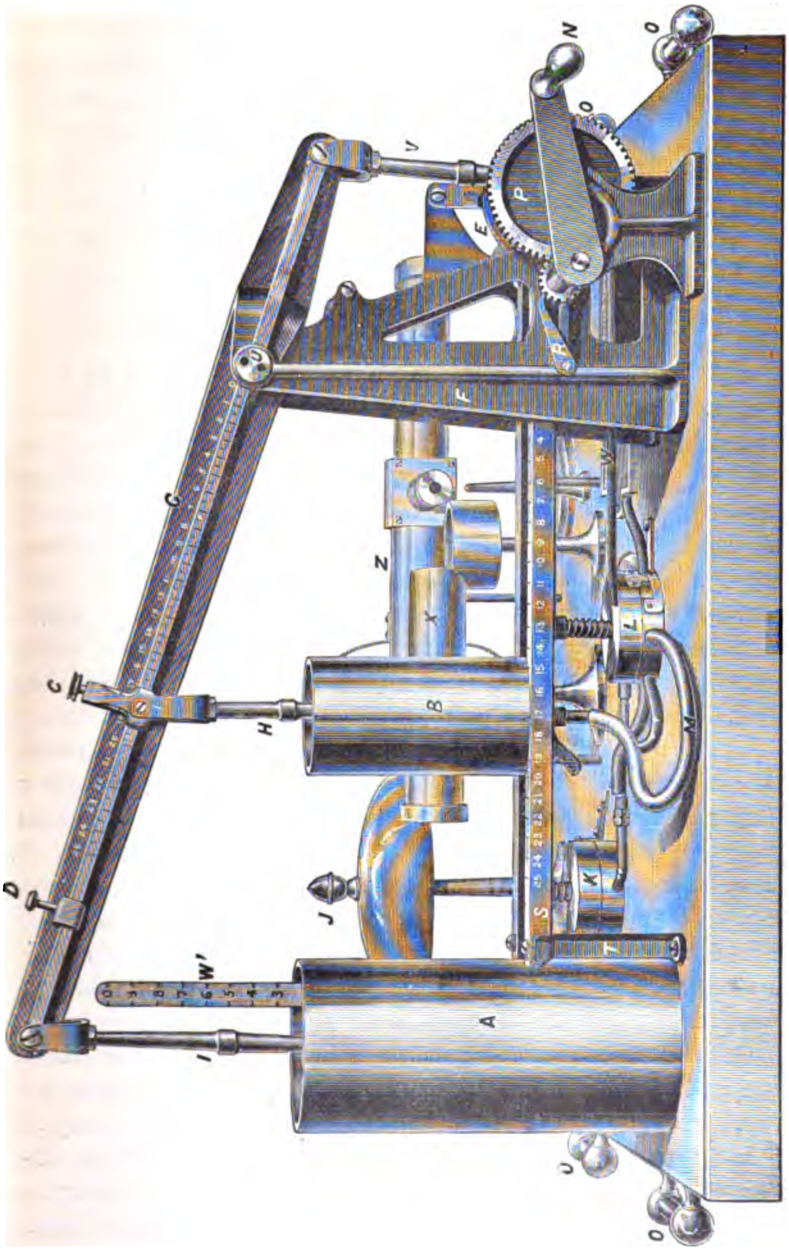


Fig. 1

from a blower in the mine, is used as a standard, or in its absence ordinary

illuminating gas may be used. For instance, 6 per cent. of the gas will ignite, 5·9 per cent. will not, 6 per cent. is then the standard line to measure from. The process of testing a bag of gas captured in the mine is very simple. Attach it to the air-cylinder of the instrument, then pump a stroke of the air from the mine, and 6 per cent. of carburetted hydrogen into the igniting chamber. If there be any fire-damp in the air from the mine, it will manifest itself at once by producing a louder detonation than that caused by the 6 per cent. of fire-damp alone or if there is a high percentage in the bag there will not be any detonation, simply a long blue flame.

It is known that there must be 6 per cent. of pure marsh gas to ring the gong by a previous determination; so if the gas-cylinder be retreated and only 4 per cent. of fire-damp be taken and the gong still rings, the extra 2 per cent. to make the gong ring must be obtained from the bag of air captured in the mine. So keep retreating the gas-cylinder until the gong will just cease to ring; the difference between the standard 6 per cent. and the point where the gas-cylinder stands at on the graduated beam will be the contents of the bag being tested, or if the gas-cylinder is at 1 per cent. it would be evident that 1 from 6 would leave 5, and that 5 per cent. would be the contents of the bag being tested. If the gas-cylinder is at 5·8 when the gong ceases to ring, 0·2 per cent. would be the contents of the bag. A 6 gallons rubber bag of fire-damp or illuminating gas, whichever is used, will last a week, testing every day.

The valuable features of a test of this character are absolute accuracy; ability to test low percentages or any percentage; and safety in making tests, for the air can be captured in the dark by means of the diaphragm hand-pump and tested in the open air far removed from the seat of danger. Air can be captured in the goaf and disused workings, and the condition of the goaf and disused workings unmasked without any danger to the miners. With the Shaw gas-tester the manager of a coal-mine is able to determine at once the condition of the gases inflammable and non-inflammable, in every air-return, to the 0·001 part, and with the knowledge of the true condition of the gases in every section of his mine, forewarned of any danger, he will be able to take proper precautions for safety. Heretofore the mine manager in the States has had to rely on the safety-lamp for the detection of inflammable gas in the different air-currents, and unless there was 2½ per cent. present, he would report "no gas," because the lamp failed to indicate the presence of gas if below this percentage. This is where all the danger lies. Supposing an air-return of 100,000 cubic feet per minute were to carry 2 per cent. of

inflammable gas, the ordinary safety-lamp would not give any evidence whatever of the presence of the gas, and the men would work in a false security based on the lamp-test, whereas actually there would be 2,000 cubic feet of gas per minute passing a given point, or enough to saturate 20,000 feet of air to the explosive point.

So long as the ventilation was kept up, and none of the doors were left open everything would be all right, and it would be impossible to ignite 2 per cent. of fire-damp; but on the other hand, if anything happened to the fan, or a door was accidentally left open, the 2 per cent. of gas travelling in the air-course would form in ten minutes 200,000 cubic feet of explosive compound. The man at the face feels the air grow hot and sultry, and realizes that the ventilation has been stopped or cut off and comes down with his light (frequently a naked light) to ascertain the reason. Ignorant of the true conditions, falsely imagining that there is no gas present, he walks into the explosive mixture with his light, an explosion follows and he, and perhaps a score of his comrades, are hurled to their death.

The detection not only of its presence, but of 0·1 per cent. of gas is not only a great achievement, but an absolute triumph over the old method of analysis, and may be termed the first mechanical analysis of gas ever made in the world. The writer could recount many tests, but having shown the great accuracy of the instrument for testing for inflammable gases, he will now go on a little further and show that its uses do not end with the testing of inflammable gases.

The instrument can be used for testing the sensitiveness of every kind of safety-lamp for coal-mines, and the manner in which it is done is as follows:—Attach a large bell jar to the instrument by means of a rubber tube, immerse the bell jar in a tank of water and displace the air in it, and place the gas cylinder at 5 per cent., pump a mixture of 5 per cent. of inflammable gas and 95 per cent. of air into the bell jar, displacing the water in the same by the inflowing current, place a lighted safety-lamp under the bell jar and immerse it in atmospheres containing 5 per cent. of inflammable gas, 6 per cent., 7 per cent., 8 per cent., or any per centage desired, which can be pumped upon the lamp, and the action of the flame witnessed through the glass. The elongation of the flame is not so noticeable in daylight as it would be in darkness, which latter is absolutely necessary for the accurate testing of the sensitiveness of safety-lamps by this method.

The next test is that for carbonic acid gas, and in order to illustrate this test, let us presume that the writer has exhaled his breath into one of

the rubber bags. Now the question is, how much carbonic gas does it contain? In order to ascertain this, the gas cylinder is placed at zero and the bag containing the author's exhalations is attached to the air cylinder only; by means of the instrument, the author passes the exhalations through a test-tube containing an ounce of lime-water until he produces a certain turbidity equal to an artificial standard of a known value. For instance, the artificial standard which the author uses represents 0·50 of a cylinder of 1 per cent. of carbonic acid gas and 99 per cent. of air. What volume of the exhalations will give the same result is determined by connecting a spray tube with the instrument by means of a rubber tube, and passing the exhalations from the bag through an ounce test-tube of lime-water, allowing the bubbles to pass up from the bottom of the test-tube and permeate in little globules through the water until the same turbidity as the standard is produced. The graduated strip on the side of air-cylinder shows that it has just taken 0·18 of a cylinder of exhalation to produce the same turbidity as 0·50 of a cylinder of 1 per cent. of carbonic acid gas and 99 of air. What does this indicate? Divide the 0·18 into 0·50 and we have 2·78 per cent. of carbonic acid gas in the exhalations just tested.

The last important feature of this instrument is its ability to demonstrate the effect of noxious gases upon animal life. The animal under treatment is placed in a bell-shaped glass cylinder 16 inches high, 4 inches diameter at the neck, and 8 inches at the base. The cylinder is placed horizontally on the table, with the neck towards the operator, and is connected with the instrument at the neck by means of a rubber tube. The animal rests on all fours, facing the operator, with its nose near the aperture through which the gases enter to the cylinder from the instrument or mixer.

The end of the bell-shaped glass cylinder is entirely open to the air, so that the mixture of gas and air is discharged and replaced every four seconds by each stroke of the pump, always maintaining a constant mixture, preventing stratification, or contamination through the exhalations of the subject. The cylinder being of glass and perfectly transparent enables the operator to observe every change in the condition of the animal.

The author found in recent experiments that he made in his laboratory that, notwithstanding the deadly claims made for carbonic acid gas, a rabbit existed with very little evidence of dissolution in an atmosphere of 25 per cent. of carbonic acid gas and 75 per cent. of air. This one fact alone is of great importance to the miner in case of an explosion followed by after-damp, for though 50 per cent. of carbonic acid gas will

overcome him very quickly, he could at least stand 25 per cent. for several minutes, or probably long enough to drag out a dying comrade, that is, in the absence of white damp or carbonic oxide gas.

Prof. P. P. BEDSON (Newcastle-upon-Tyne) wrote that he had read with great interest the description of the Shaw gas-tester for detecting and estimating fire-damp. The method of estimation, based upon the determination of the amount of fire-damp required to be added to a given sample of gas to make an explosion of given effect, was certainly original. The mechanical appliances by which this was rendered possible displayed great ingenuity. The only point upon which he had any misgivings—which would possibly be removed by an actual examination of the apparatus—was the possibility of distinguishing to the nicety claimed by the author between explosive mixtures exhibiting such slight variations in composition as those cited.

Mr. JAMES ASHWORTH (Derby) wrote that the Shaw apparatus appeared to him to be cumbersome, unwieldy, and totally unsuitable for the requirements of coal-mines. As a mechanical device it undoubtedly did not follow in the beaten track of the Davy and Stephenson safety-lamps. It, however, had one point in common with these and all other safety-lamps, viz., that the test for gas was made with "fire." Thus compared, it stood at a great practical disadvantage, and this disadvantage was increased by its very high prime cost, and because its deductions were liable to most serious inaccuracies in practical use. He did not dispute the possibility of finding the correct percentage of fire-damp, or carbon monoxide, or carbon dioxide, or sulphuretted hydrogen, if each is present by itself and mixed with air, but if there were such an ordinary mixture as fire-damp, carbonic oxide, and carbonic acid gases with air, together with others from gob-fire, it appeared to him that the apparatus could not possibly give a correct result. It was therefore essential that the composition of the gaseous mixture should be known before a really practical use of the machine could be made. Mr. Wilson was undoubtedly right in stating that heretofore the mine manager in the United States of America had had to rely on the safety-lamp for the determination of inflammable gas, and that unless there were 2½ or more per cent. present he would report "no gas," and it was much the same in this country, where the majority of the safety-lamps used by deputies and firemen and other officials would not indicate a percentage less than 2½. The danger arising from this cause

had been increased by the compulsory bonneting of the Davy safety-lamp—a lamp Mr. Wilson singled out as being the most sensitive for the detection of fire-damp, excepting only the alcohol or hydrogen lamp.

The PRESIDENT said the Shaw apparatus certainly appeared to be an ingenious application of mechanical methods to the analysis of gas; he thought no satisfactory opinion as to its practical use could be arrived at until it had been actually tested. Although it seemed to have been somewhat widely used in America, it was doubtful whether it was of such great value as to warrant its introduction into Great Britain, as the Pieler and other forms of alcohol gas-testing lamps, and the hydrogen gas-tester, would show as little as $\frac{1}{4}$ per cent.

Mr. J. L. HEDLEY (H.M. Inspector of Mines) said that he did not desire to detract at all from the value of the Shaw apparatus as a gas-detector, but the important point—to be considered in relation to an apparatus of this kind—was its practicable applicability for use in mines, in which the conditions varied from day to day, from hour to hour, and even from one minute to another. This apparatus, he understood, had been adopted as the official standard by the legislatures of the States of Ohio and Pennsylvania. He would like to know what was done when certain percentages of gas were detected, and whether any extra precautions were taken when the percentage of gas exceeded a given amount. It appeared to him that even if they could get a normal state of affairs throughout the pit the whole day long there should be some governing regulations, even if these instruments were used, fixing the percentages of gas beyond which the miner should not be allowed to work. He thought that this apparatus could only be used by certain persons and at certain times, and it always seemed to him that in introducing such appliances unless proper precautions were taken they incurred the additional risk of diminishing the care taken by the officials in their examinations, by the ordinary means, of the working-places for gas. This instrument could not be taken into every working-place (it was too heavy), and he very much feared that if used alone and for the reasons already stated, they would be adding to the risks that they already ran rather than reducing them. He, for one, would be sorry to see the present mode of testing for gas with a safety-lamp superseded by the Shaw gas-tester, although he would welcome the latter as supplementary to the former.

Mr. A. L. STEAVENSON (Durham) suggested that each of H.M. Inspectors of Mines should be provided with a Shaw gas-tester, and that they should visit each mine periodically and take samples of the air in the main return airways. The fact that the instrument cost £100 should not

stop the use of the machine if it were really useful. Many colliery owners had spent thousands of pounds on new ventilating fans, and the cost should not prevent the adoption of any measure of safety. The question, however, was as to whether it was really a useful machine ; it might be possible to examine air in one place and find no gas, yet within 8 feet gas might be found in abundance. The machine consequently could only be useful for testing for gas in the return airways, and would be of no use in the testing the edges of a goaf for gas, where such accuracy as 0·10 per cent. was not required or desired. It was not the practice in Great Britain, although it might be American practice, for a miner, finding himself warm, to go with a naked light in his hand to see whether the ventilation had been cut off, as had been pictured by the writer. There were several machines already in use for gas-testing which would record as little as ½ per cent. of gas. The Liveing machine had been proved very satisfactory in practice ; it did not weigh more than 6 pounds, while the Shaw gas-tester weighed 90 pounds.

Mr. H. G. GRAVES (London) said that the machine had been tested by Mr. H. Le Chatelier, who gave an account of his experiments in the *Annales des Mines*.* He found that the results were practically accurate within a small percentage, but he condemned its use, as owing to its being so cumbrous, it could only be used on the surface. Mr. Le Chatelier had designed a small test-tube arrangement to be used in its place, the details of the use of which had been described by Mr. L. Poussigue in the *Bulletin de la Société de l'Industrie Minérale*.†

Mr. J. L. HEDLEY remarked that the gathering of a sample of the air of a mine in a test-tube would only show the state of the mine at the particular moment, and could not be taken as a standard of the condition of the atmosphere of the mine for a length of time, or for any part of the mine, other than that particular point from which the sample was taken.

Mr. M. WALTON BROWN (Newcastle-upon-Tyne) said that the use of such appliances as the Shaw gas-tester necessitated the use of apparatus for obtaining average samples of the air of the mine over periods which could be varied as desired. A simple form of apparatus for such a purpose would consist of a closed vessel fitted with two taps: the apparatus being filled with water and the upper tap opened, the lower tap can then be opened so as to allow of the escape of the water in any required time, and the vessel will be filled with an average sample of the air of the mine. This average sample, however, would by no means represent the most dangerous atmosphere prevailing at that point of the mine.

* Series 8, vol. xix., page 388. † Series 3, vol. vi., page 249.

Mr. A. L. Steavenson said there did not appear to be any certainty that the results recorded by the Shaw gas-tester were really accurate. They were obtained by a mechanical apparatus, and it was quite possible that the results were not correct.

Prof. F. Clowes wrote that the matter treated of was of the greatest interest to the writer, and he had occasion twelve months ago to correspond with Mr. Shaw, and to carefully study and consider his gas-tester, in order to form as satisfactory an opinion upon its suitability and merits as was possible without actually handling the instrument. Practical men who had taken part in the discussion had fully appreciated and referred to most of the important points. He considered that if the Shaw apparatus were the only accurate and delicate gas-tester it would be rash to discard it on the score of its cost and cumbrousness, and because the samples of air had to be collected, stored, and brought to the surface to be tested. But there existed at present cheap and easily portable forms of apparatus, some at least of which were equal in accuracy and delicacy to the Shaw tester. They presented the great advantage of being able to be carried into the pit, and they gave at once rapid tests for gas in *situ* down to the limit of 0·1 per cent.; they avoided therefore the very unsatisfactory process of collecting and transporting samples of the mine air to the surface. The inconvenience and delay occasioned by this collection and transport of gas samples, the fact that when collected they represented only one particular spot at one particular time, and that they were liable to undergo change in composition before they were tested, were all strong reasons for giving preference to a portable tester. These forms of portable apparatus further avoided the necessity of keeping a supply of pure marsh gas, which is a requisite of the Shaw tester, since in the delicate testing referred to by the writer of the paper the use of coal-gas of variable composition is inadmissible. Most of the forms of improved testing apparatus which are, with good reason, in favour at present are flame-tests, applied in suitable safety-lamps. The flame-test has the great advantage that it is the test commonly in use; it can therefore be at once taken up by any official who has made ordinary tests with the safety-lamp. The apparatus required is simple, non-fragile, and yields its results at once without lengthy experiment, calculation or correction. A brief description and criticism of the different gas-testing safety-lamps by the writer will be found in the report of the Cantor lectures given before the Society of Arts at the beginning of the current year. The writer has confined his criticism to the application of the Shaw tester to gas-testing in the coal-mine, and to the examination of

other forms of gas-testing apparatus. There seems to be no doubt that when applied to other purposes requiring a current of mixed gases of known composition, the Shaw apparatus will prove of the greatest service, and as an ingeniously contrived mechanical apparatus it cannot fail to excite admiration.

Mr. W. S. GRESLEY (Erie, Pennsylvania) wrote that he had had no experience with the Shaw gas-tester, but a few years ago he elicited the opinions of some of the Pennsylvanian state mine inspectors as to its use. These gentlemen were of opinion that, provided the whole of the apparatus was in perfect working order, by proper manipulation it could be made to indicate with sufficient accuracy that which its inventor claims for it. But as to whether the machine would ever be of any practical use in preventing gas-explosions in mines, and thereby become any real safeguard to life and property, they seemed very doubtful; they did not see how it could ever displace the "fire boss" (deputy or underviewer) and his safety-lamp.

The PRESIDENT proposed a vote of thanks to Mr. Wilson for his paper, which was agreed to.

The PRESIDENT proposed that a cordial vote of thanks be given to the owners of collieries to be visited during the course of the meeting, and to the Blyth Harbour Commissioners, the River Tyne Commissioners, and the North Eastern Railway Company, for the steamers and special train placed at the service of the members.

Mr. GEORGE MAY seconded the proposal, which was very cordially adopted.

Mr. ARTHUR SOPWITH proposed a vote of thanks to the North of England Institute of Mining and Mechanical Engineers, for the arrangements which they had made for the reception of the members. The programme of the meeting was an admirable one, and more especially so, as the arrangements confined the members in one party throughout the various excursions.

Mr. JAS. BARROWMAN (Hamilton) seconded the proposal, and the vote was heartily adopted.

Mr. FORGIE moved, and Mr. J. L. HEDLEY seconded, that their hearty thanks be accorded to the President for his services in the chair.

The PRESIDENT briefly acknowledged the compliment, and the meeting then terminated.

The following notes record some of the features of interest seen by visitors to collieries, etc., which were, by kind permission of the owners, open for inspection during the course of the meeting on September 5th, 6th, and 7th, 1894:—

TYNE COMMISSIONERS' WORKS.

The most important work of the Tyne Improvement Commissioners is the Tyne Piers, the original general plan of which was designed by the late Mr. Walker. Their construction commenced in 1856, under the superintendence of Mr. P. J. Messent, by whom the details of the construction of the works have been designed and carried out. The piers are intended to protect vessels from the frequent and destructive easterly gales, and to facilitate the removal and prevent the re-formation of the bar at the entrance to the harbour. These works, among the most difficult of the kind in progress or executed in any part of the world, on account of the violence of the seas to which they are opposed, are now completed above high-water, and only require protective aprons (now nearly completed) around the heads, formed of heavy (about 36 tons) foreshore blocks, placed by divers at a level of between 20 and 30 feet below low-water. Each pier is formed of a base of rubble stone, deposited from barges, and a superstructure of concrete and masonry, the lower and larger portion of which was fixed by divers, commencing at a depth of 30 feet below low-water. The length of the north pier is 3,053 feet, and that of the south pier 5,310 feet. About 3,000,000 tons of stone, exclusive of lime and cement, have been used in these works. The mammoth cranes, designed by Mr. P. J. Messent, for extending the masonry superstructure of the piers without staging, are capable of setting blocks of weights of upwards of 40 tons, at a distance of 92 feet from the central pivot.

Since the year 1861, the bar at the mouth of the river has been removed to a depth of over 20 feet, which depth is maintained beyond the inner bar for a considerable width in Shields Harbour. The Narrows have been widened from 400 feet to 670 feet. The dangerous shoals have been removed from Shields Harbour, and a depth of at least 30 feet at low-water has been formed for a length of about 1½ miles. The tortuous course of the channel has been straightened, and vessels can leave the river at or within a short time of low-water.

There is now a depth of at least 20 feet between the harbour and Newcastle, where vessels used to ground for several hours at low-water. Two dredgers are still at work continuing a depth of over 18 feet at low-water above Newcastle. Since the commencement of the present year

these improvements have enabled a large number of vessels passing through the Tyne opening bridge to load cargoes of coal at the staiths recently erected by the North-Eastern Railway Company at Dunston.

These improvements have been chiefly effected by dredging. The plant consists of 6 dredgers, 10 steam hopper-barges, 44 wooden hopper-barges, 8 steam tugs, and numerous keels, boats, etc. Over 90,000,000 tons of materials have been dredged from the river, and deposited in the sea two or three miles from the entrance to the river.

At Newcastle, the old bridge of stone, an obstruction to navigation and the flow of the tide, has been removed, and a Swing Bridge constructed. This bridge contains four openings for river traffic, corresponding with those of the High Level Bridge. The two central openings, each of 104 feet, are spanned by a girder, made to swing round and allow masted vessels to pass. The north and south side openings are 92½ and 64½ feet respectively, and available for the passage of vessels with folding masts and funnels. The piers and abutments of the bridge are made of stone and concrete, sunk down to the rock at a depth of 45 feet below low-water. The girder of the swing bridge is 280 feet long, weighs 1,450 tons, and will safely allow the passage of a load of 60 tons on a four-wheeled vehicle.

Friars' Goose Point and Bill Quay Point are in course of removal, by which the width of the river will be materially increased. Bill Point, projecting 400 feet, and involving the excavation of 2,000,000 tons of rock and clay, has been removed. The removal of Whitehill Point, when completed, will widen the river there to the extent of 300 feet.

There are three enclosed docks on the River Tyne. The Northumberland or Howdon Dock has a water area of 58 acres and 24 feet of water on the sill at high tide. It is chiefly used for shipping coal, and is the property of the Tyne Improvement Commission.

The Tyne Dock, belonging to the North Eastern Railway Company, also has a water area of 58 acres, and is chiefly used for shipping coal, of which about 27,000 tons are loaded daily ; the depth on the old sill is 24¾ feet at high water, and the new entrance, with greater depth of water, is nearly completed.

The Albert Edward or Coble Dene Dock (for imports and exports) was constructed by the Tyne Improvement Commissioners from the joint design of the late Mr. J. F. Ure and of Mr. P. J. Messent ; it has a water area of 27 acres, and is surrounded by 2,600 feet of deep-water quays. Provision is made for its ultimate extension and junction with the Northumberland Dock, and there is a river wall, 900 feet long in front of

the dock. There is 30 feet of depth at high-water spring tides on the entrance and upper lock sills, and 36 feet on the lower or outer sill of the lock. The average rise of spring tides being 15 feet, the depths at neap tides are 4 feet lower at high-water and 4 feet higher at low-water. On the west quay of the Albert Edward Dock is a large warehouse for grain and general merchandise, 200 feet long by 100 feet broad, containing six floors, each fitted with hydraulic machinery and all necessary appliances. Inside the dock there is a large coal-shipping staith. The Norwegian royal mail and passenger steamers sail every week day between this dock and Norway.

Between the Northumberland and Albert Edward Docks is a riverside wharf 1,100 feet long and 144 feet wide, with quays and standage ground and two warehouses. Above the wharf are two coal-shipping staiths which project 97 feet into the river. The staiths are self-acting; the loaded wagons descend by gravity to the spouts, and the empty wagons run off the staith to a lower level. Each staith has three spouts, by which coal can be simultaneously loaded into the three hatchways of a large ship at the rate of 800 to 1,000 tons per hour. Eastward of these recently erected are two staiths similarly constructed, but with two spouts each, and a third staith for small coals.

During the year 1891, 11,086,823 tons of coal and coke were shipped from the Tyne, and the volume of general trade, coastwise and foreign, was—

	Tons.
Exports (exclusive of coal and coke)	669,839
Imports	1,666,195
Total	2,336,034

BLYTH HARBOUR.

Blyth harbour is situate at about the centre (measuring north and south) of the Northumberland coal-field, and about 8 miles north of the river Tyne. There are upwards of 20 collieries within a radius of 4 miles, and about 20 others in the neighbourhood, for which Blyth harbour is the natural port of shipment.

There are 14 coaling-spouts at the harbour, most of them being upon the most improved principles, adapted to load into two hatchways of a vessel at one time, and having a depth of water alongside of 29 feet to 34 feet at high-water. The entrance-channel from the sea has a depth of 28 feet at high-water.

By the continuous improvement of the harbour, trade has developed so rapidly that it has been found necessary to provide further accommodation for vessels and greater facilities for shipping coal. The Harbour Commissioners are now increasing the deep-water area of the harbour to the extent of 35 acres, and are providing coaling-staiths capable of shipping 2,000,000 tons of coal per annum, and deep-water import and export wharves with railway-sidings and connexions.

There are quays for the discharge of timber, ballast, and general goods; five graving-docks for the repair of vessels, and land available for factories, shipbuilding-yards, etc. Both sides of the harbour are connected with the North Eastern Railway system, and with all parts of the country.

The shipments of coal at the harbour during a few recent years are as follow:—

From	November 1st,	1882,	to	October 31st,	1883,	146,264	tons.
"	"	1883,	"	"	1884,	362,879	"
"	"	1884,	"	"	1885,	526,667	"
"	"	1885,	"	"	1886,	561,749	"
"	"	1886,	"	"	1887,	585,484	"
"	"	1887,	"	"	1888,	1,018,335	"
"	"	1888,	"	"	1889,	1,263,327	"
"	"	1889,	"	"	1890,	1,715,406	"
"	"	1890,	"	"	1891,	2,047,480	"
"	"	1891,	"	"	1892,	2,157,140	"
"	"	1892,	"	"	1893,	2,342,020	"

ASHINGTON COLLIERY (BOTHAL WEST HARTLEY).

This colliery has an output of about 4,300 tons of coal per day.

There are three shafts situated together near Ashington Station which form one establishment, with a daily output of about 4,000 tons of coal. The depth of the shafts to the low main seam is 540 feet.

The underground haulage is on the endless-rope system, and the workings are carried to the dip 340 feet below shaft-level. The underground pumps are in part worked by compressed air and in part by endless-ropes, upwards of 18 miles of ropes being in daily use for these purposes.

The feeders of water are raised to the surface by pumps 25 inches in diameter, delivering 1,100 gallons per minute. A supply of pure water for the inhabitants of the village is forced to the surface by independent machinery in duplicate, so that the supply may be continuous in case of accident.

Steam is supplied by twenty boilers fitted with automatic stoking bars and forced-draught furnaces.

The electric light is supplied in several of the departments.

Vibrating screens and travelling-belts are employed in preparing the coal and separating it as required for the market. A Bell and Ramsay washer is also in use.

The coal supply to the workmen and others and the scavenging of the colliery village are worked by means of narrow-gauge railways, of which there are upwards of 6 miles.

Bricks are being made from fire-clay by the semi-dry process.

CAMBOIS COLLIERY.

The low main seam is being worked at a depth of 630 feet. The seam is 4½ to 5 feet in height, and is worked on the board-and-pillar system. The output is about 1,200 tons per day, the greater portion being worked from the undersea area.

The vertical condensing winding-engine has one cylinder 65 inches in diameter and 7 feet stroke. The drum is 22 feet in diameter. It draws 4 tubs at once, each of the gross weight of 21 cwts.

The haulage, on the main-and-tail-rope system, is effected by 3 semi-portable engines (underground). The cylinders are 14, 14, and 12 inches respectively in diameter, and the drums 6 feet in diameter.

The underground pumping-engine has 2 cylinders, each 22 inches in diameter and 5 feet stroke, rams 9 inches in diameter, forcing 400 gallons of water per minute to a vertical height of 650 feet, through pipes 13 inches in diameter.

The electric pumping-plant (at bank) consists of a Robey trip-gear engine and a 40 unit Tyne dynamo, which drives 6 underground pumps at distances of 3,600, 5,400, 5,700, 6,600, and 6,900 feet from the shaft. The pumps are 6 and 8 inches in diameter, 18 inches stroke, and are connected by worm-gearing to 6 horse-power motors. The total length of electric cable in use is nearly 8 miles.

There is also an electric lighting plant, and a Robinson coal-washer of 250 tons capacity.

The colliery is connected by private line with the company's shipping spouts at North Blyth.

NORTH SEATON COLLIERY.

The seams worked are the yard and low main, at the depths of 558 and 750 feet respectively. The yard seam is 2½ to 3 feet in thickness, and is worked on the longwall system. The low main seam is 4 to 5 feet in height, and is worked on the board-and-pillar system. The output is about 1,100 tons per day.

The vertical condensing winding-engine has a cylinder 60 inches in diameter and 7 feet stroke. The drum is 22 feet in diameter. It draws 4 tubs at once, each of the gross weight of 21 cwts. An endless-rope counterbalance is used under the cages in the shaft.

The haulage on the main-and-tail-rope system in the low main seam is effected by an horizontal engine, placed underground, with two cylinders, each 20 inches in diameter, and 30 inches stroke. The drums are 8 feet in diameter. The endless-rope system is in use in the yard coal-seam, gravitating to the shaft through a drift to the low main seam.

A compound condensing Worthington pumping-engine, placed underground, is forcing 750 gallons of water to a vertical height of 800 feet, through a wrought iron main, 10 inches in diameter. The high-pressure cylinders are 18 inches in diameter, the low-pressure cylinders are 30 inches in diameter, the rams are 9 inches in diameter, and 30 inches stroke. A vertical beam pumping-engine, on the surface, held in reserve, with a cylinder 78 inches in diameter and 6 feet stroke, works pumps 26, 20, and 18 inches in diameter.

The electric pumping-plant comprises an engine at bank, with a cylinder 13 inches in diameter and 10 inches stroke, driving a Tyne dynamo, connected by concentric cable to an underground pump 8,000 feet distant. The three-throw pump is worked by means of worm-gearing; the rams, 9 inches in diameter and 15 inches stroke, are pumping about 250 gallons of water per minute.

The screening plant comprises jigging screens, picking-belts, mechanical tipplers, 200 tons Robinson coal-washer, etc.

There is also an electric lighting plant.

NEW HARTLEY COLLIERY.—HASTINGS PIT.

The shaft, 16 feet in diameter, is sunk 330 feet to the yard coal-seam, which is worked on the longwall system.

The horizontal winding-engine has two cylinders, each 28 inches in diameter, and 54 inches stroke; fitted with drum, 14 feet 4½ inches in diameter. The cages have two decks, carrying 4 tubs, each containing 8½ cwts. of coals.

The horizontal hauling-engine (underground) has two cylinders, each 18 inches in diameter and 36 inches stroke; it is geared 2½ to 1, and is working an endless-chain system of haulage. Steam is passed to this engine from the surface.

The compound differential pumping-engine on the surface has cylinders 24 inches and 44 inches respectively in diameter, and 7 feet stroke. There are two rams at the pit-bottom, each 17½ inches in diameter, and of the same stroke, worked by means of quadrants and spears. About 500 gallons per minute are now forced to a vertical height of 384 feet, but the engine has pumped 1,570 gallons per minute.

The colliery is ventilated by a Guibal fan, 30 feet in diameter producing 108,000 cubic feet of air per minute, under a water-gauge of 1·30 inches.

Electric lighting is applied on the surface and underground.

The Melton pit, 13 feet in diameter, 336 feet to the yard coal-seam, is being sunk to the low main seam.

SEGHILL COLLIERY.

The output of about 1,200 tons of coal per day is drawn from two shafts.

The colliery is ventilated by an open-running fan 35 feet in diameter. The fan is driven by a Corliss engine having one steam cylinder 16 inches in diameter and 3 feet stroke, with sugar-tongs clip valve-gear. The engine is controlled by a governor which automatically varies the cut-off and maintains a regular speed even when the steam pressure varies 20 lbs. per square inch. The speed is readily varied by altering weights placed on the governor, and this change can be effected while the engine is running.*

Revolutions of Fan per Minute.	Volume of Air per Minute.	Indicated Horse-power of Fan Engine.	Steam Used.			Small Coal Used per Year of 365 Days.
			Per Indicated Horse-power per Hour.	Per Day.	Per Year of 365 Days.	
	Cubic Feet.		Lbs.	Tons.	Tons.	Tons.
40	87,940	29·61	35·57	11·281	4,117	560
60	135,742	96·11	27·12	27·927	10,193	1,437

A vertical engine, with a cylinder 9½ inches in diameter, 9 inches stroke, running at 200 revolutions per minute, drives a 15 horse-power dynamo producing a current of 460 volts. The electric energy is transmitted through a 7/16 insulated cable to a 10 horse-power motor placed in the low main seam, nearly a mile distant from the shaft. This motor drives a three-throw ram-pump delivering 100 gallons of water per minute

* *Trans. Fed. Inst.*, vol. vi., page 48.

to a vertical height of 120 feet through two pipes 4 inches in diameter. The useful effect is 32 per cent.* A few electric incandescent lights are attached to this dynamo.

The haulage, on the main-and-tail-rope system, is worked by a horizontal engine, with a cylinder 13½ inches in diameter and 30 inches stroke ; the cylinders are steam-jacketted, and fitted with valve-gear, controlled by a governor, which automatically varies the cut-off, and maintains a constant speed of engine. The speed may be varied from 70 to 100 revolutions per minute by altering a spring attached to the governor, even while the engine is in motion. When not hauling, the tail-rope drum can be put out of gear, a clip-wheel put into gear, and the power transmitted by an endless wire-rope to the main pumping-engine in the low main seam. This engine, when running at 70 revolutions per minute, indicates 66 horse-power, and pumps 200 gallons of water per minute from a depth of 510 feet.

A similar engine works the endless-rope haulage in the yard seam with over 2 miles of rope. A smaller engine, with a cylinder 10½ inches in diameter and 22 inches stroke, works the endless-rope haulage in the blake seam with over 6 miles of rope.

All these engines are worked by steam at a pressure of 100 lbs. per square inch, and the steam for the whole of the collieries is generated by four Lancashire boilers, fired by hand with small coal.

THE EXPERIMENTAL EXPLOSIVES STATION OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

The North of England Institute of Mining and Mechanical Engineers have been conducting for some months, at their own expense, important experiments on flameless high explosives.

The labours of the committee have been up to the present time directed to the behaviour of ammonite, ardeer powder, bellite, carbonite, roburite, and securite, when fired into mixtures containing from 1 to 10 per cent. of mine-gas or coal-gas.

The experiments are being conducted in a large shed, which is singularly appropriate to the purpose to which it is now applied. The firing-chamber consists of a cylindrical tube, 100 feet long and 3 feet in diameter, made of boiler plates, and a cannon, mounted on a carriage and

* *Trans. Fed. Inst.*, vol. iv., page 132.

capable of being brought close up to one end of the chamber, serves for holding and firing the charge of explosive. The chamber has safety-vents placed at intervals along the top, which are closed by wooden plugs loosely knocked in, and, in addition, there are numerous sight-holes, glazed with thick glass, for observing the interior. There are other arrangements: for ensuring the delivery of a measured volume of gas into a definite volume of air; for effecting the perfect admixture of the gaseous mixture; for taking samples of the mixture before or after ignition; for taking its temperature; for providing for the presence of dust of any kind in suspension, or *in situ;* and for other purposes, all of which indicate how carefully and thoroughly the investigations have been planned and executed by the committee of the Institute.

The experiments shown to the visitors included the firing of blasting-powder into ordinary air; into an inflammable mixture of natural fire-damp and air; into ordinary air with coal-dust in suspension; and into ordinary air with coal-dust *in situ.* Before commencing any experiment, the far end or mouth of the firing-chamber was covered with a sheet of brown paper.

In the air, with gunpowder alone, a bright flash was observed in the chamber, and the brown paper was blown off the end of the tube; when coal-dust was present, whether in suspension or *in situ,* the flash was considerably brightened and lengthened, and not only was the brown paper blown off the end of the tube, but a huge cloud of smoke was propelled for a distance of more than 100 feet beyond the mouth of the tube, and many of the plugs were forcibly projected from the safety-vents, being followed by rushing columns of thick black smoke, and in some instances by flame; very suggestive of the inflammability of mixtures of coal-dust and air.

The force of an ignition of fire-damp and air was equally well exhibited, and in this case two flashes were observable, the first being due to the ignition of the blasting-powder, the second to the ignition of the gaseous mixture.

The experiments were very successfully carried out by Mr. A. C. Kayll the engineer to the committee, all points being clearly explained, and the apparatus lucidly described by Mr. J. L. Hedley, H.M. Inspector of Mines.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, OCTOBER 13TH, 1894.

MR. THOMAS DOUGLAS, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the previous General Meeting, and reported the proceedings of the Council at their meetings on September 29th and that day.

The proceedings of the Council of The Federated Institution of Mining Engineers were reported.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. WILLIAM HENRY ANGOVE, Engineer, Albany, Western Australia.

Mr. JAMES FORD DAVISON, Mining Engineer, Yarlside, Dalton-in-Furness.

Mr. JONATHAN DIXON, Colliery Manager, Homeville, West Maitland, New South Wales.

Mr. JOHN THOMAS FOULIS, Mine Agent, 42, Demesne Road, Douglas, Isle of Man.

Mr. GEORGE C. HOOPER, Surveyor of Mines, Whitehaven Collieries, Whitehaven.

Mr. HENRY THORNTON NEWBIGIN, Engineer and Manager, c/o Messrs. M. Coulson & Co., Spennymoor.

Mr. HORACE PRATT, Colliery Manager, Jobs Hill, Crook.

Mr. JAMES RUSSELL, Mine Manager, etc., Ukalunda, via Bowen, Queensland.

Mr. CHARLES TURNER SANER, General Manager, Van Ryn Estate and Gold Mining Co., Limited, P.O. Box 357, Johannesburg, Transvaal.

Mr. GEORGE A. SPOTSWOOD, Mining Engineer, 46, Clarence Street, Kingston, Ontario, Canada.

Mr. THOMAS PRESSICK YEOMAN, Mining Engineer, Bengal Coal Co., Giridih, Bengal, India.

ASSOCIATE MEMBERS—

Mr. BENJAMIN ROBINSON BANYER, Mining Student, School of Mines, Kapunda, South Australia.

Mr. EDWARD ECCLES, King Street, Newcastle-upon-Tyne.

Mr. RICHARD JOHN MIDDLETON, Manager of the *Mining Journal*, 18, Finch Lane, London, E.C., and The Lilies, Balfour Road, Highbury New Park, London, N.

Mr. B. J. TOWNSEND, Toronto, Ontario, Canada.

Mr. ARTHUR WATSON, Mining Student, Hamsterley Colliery, Ebchester, Co. Durham.

Mr. JOHN WEATHERBURN, Draughtsman, 53, Cuthbert Street, Gateshead.

ASSOCIATES—

Mr. THOMAS BATTEY, Overman, Percy Terrace, Backworth Colliery.

Mr. WILLIAM RALPH BELL, Assistant Under-manager, Wearmouth Colliery, Sunderland.

Mr. JOSEPH STANLEY COWELL, Assistant Under-manager, Wearmouth Colliery, Sunderland.

Mr. THOMAS PROCTOR, Overman, Ashington Colliery, Northumberland.

Mr. JOSEPH C. SOUTHERN, Master Wasteman, Harraton Colliery, Washington, R.S.O., Co. Durham.

STUDENTS—

Mr. EDWARD HERBERT CLIFFORD, Mining Student, 24, Gledstanes Road, West Kensington, London. S.W.

Mr. MICHAEL FALCON, Mining Student, Thwaites' Parsonage, Millom, Carnforth.

Mr. JAMES ARTHUR IMESON, Articled Apprentice, Wearmouth Colliery, Sunderland.

Mr. ERNEST MCGOWAN, Articled Apprentice, Wearmouth Colliery, Sunderland.

Mr. H. G. RAEBURN, Mining Student, Redheugh Colliery, Gateshead.

SUBSCRIBING MEMBER—

Messrs. JOHN MILLS & SONS, Limited, Collingwood Street, Newcastle-upon-Tyne.

The following gentlemen were nominated for election :—

HONORARY MEMBER—

Mr. WILLIAM GARNETT, M.A., D.C.L., 13, Spring Gardens, London, S.W.

MEMBERS—

Mr. B. ANGWIN, Mining Engineer, P.O. Box 231, Johannesburg, Transvaal.

Mr. GEORGE BELLINGHAM, Licensed Land and Mining Surveyor, Coolgardie, Western Australia.

Mr. ALFRED HAMMOND BROMLY, Mining and Mechanical Engineer, Llannwchllyn, near Bala, North Wales.

Mr. RONALD C. CAMPBELL-JOHNSTON, Metallurgist, Assayer, and Mining Engineer, P.O. Box 40, Vancouver, British Columbia.

Mr. HENRY REYNOLDS CHAPMAN, Mechanical Engineer, Victoria Works, Gateshead-upon-Tyne.

Mr. ROBERT EDDEN COMMANS, Mining Engineer, 6, Queen Street Place, London, E.C.

Mr. RICHARD STAFFORD COUSINS, Civil Engineer, Coach Road House, Whitehaven.

Mr. ROBERT FOWLER, Colliery Manager, Washington Colliery, Washington Station, R.S.O.

Mr. HENRY RICHARD HANCOCK, Superintendent, Wallaroo and Moonta Mines, Moonta Mines, South Australia.

Mr. REIJI KANDA, Mining Engineer, c/o Mr. Takahira Kanda, 9, Awajicho-Nechome, Kanda, Tokio, Japan.

Mr. H. W. FERD KAYSER, Mining Engineer, The Mount Bichoff Tin Mining Company, Waratah, Tasmania.

Mr. WILLIAM LECK, H.M. Inspector of Mines, Cleator Moor, Cumberland.

Mr. DUNCAN McGEACHIE, Manager, Waratah Colliery, Charlestown, near Newcastle, New South Wales.

Mr. D. H. F. MATTHEWS, H.M. Inspector of Mines, Newton-le-Willows.

Mr. JAMES JONES MELDRUM, Manufacturing Engineer, Atlantic Works, City Road, Manchester.

Mr. SEPTIMUS OLIVER, Mining Engineer, Tyne House, Tynemouth.

Mr. FREDERICK DANVERS POWER, Mining Engineer and Metallurgist, c/o Messrs. Henderson & Macfarlane, 2, Bridge Street, Sydney, New South Wales.

Mr. WILLIAM EDWARD SAM, Jun., Mining Engineer, c/o Messrs. F. & A. Swanzy, Cape Coast Castle, Gold Coast.

Mr. HARRY SLADDEN, Mining Engineer, Chorlton Chambers, P.O. Box 1666, Johannesburg, Transvaal.

Mr. GEORGE PATON WALSH, Engineer, 138, Reguliersgracht, Amsterdam, Holland.

Mr. HORACE V. WINCHELL, Geologist and Mining Expert, 316, Tenth Avenue, S.E., Minneapolis, Minn., U.S.A.

ASSOCIATE MEMBERS—

Mr. ALFRED MOLYNEUX PALMER, Coal Owner, 14, Windsor Terrace, Newcastle-upon-Tyne.

Mr. SYDNEY C. RUDMAN, Land Agent and Engineering Surveyor, Estate Office, Windlestone, Ferryhill.

Mr. ROBERT SHEARD, Engineer and Boiler Builder, Caldervale Boiler Works, Wakefield.

Mr. G. YOUNG WALL, Manorial Surveyor and Local Deputy Steward to the Ecclesiastical Commissioners for England, Halmote Court Office, New Exchequer Buildings, Durham.

ASSOCIATES—

Mr. ARTHUR MORTON HEDLEY, Assistant Overman, Barrow Collieries, Barnsley.

Mr. JAMES STOKOE, Overman, Murton Colliery, *via* Sunderland.

STUDENTS—

Mr. JOHN HENRY BACON FORSTER, Mining Student, Hetton Colliery, Hetton-le-Hole, R.S.O.

Mr. NATHANIEL MAURICE GRIFFITH, Mining Student, c/o Broughton & Plas Power Coal Co., Ld., Wrexham.

Mr. TOM ALFRED LISHMAN, Mining Student, The Tower, Durham.

Mr. ALBERT LITTLEJOHN, Mining Student, Ashington Colliery Offices, Morpeth.

Mr. PHILIP NEASHAM, Mining Apprentice, Colliery Office, Medomsley, Co. Durham.

Mr. NORMAN NISBET, Mining Apprentice, Tantobie, Co. Durham.

AWARDS FOR PAPERS.

The SECRETARY read the following list of papers read during the year 1893-94, for which prizes had been awarded by the Council to the authors:—

"A Contribution to our Knowledge of Coal-dust. Part II." By Dr. P. Phillips Bedson.

"A Contribution to our Knowledge of Coal-dust. Part III." By Dr. P. Phillips Bedson and Mr. W. McConnell, jun.

"The Combustion of Oxygen and Coal-dust in Mines." By Mr. W. C. Blackett.

"History and Description of the Greenside Silver Lead Mine, Patterdale." By Mr. W. H. Borlase.

"The Choice of Coarse and Fine-crushing Machinery and Processes of Ore Treatment." By Mr. A. G. Charleton.

"The Ghorband Lead-mines, Afghanistan." By Mr. A. L. Collins.

"Note on the Antimony Deposit of El Altar, Sonora, Mexico." By Mr. Edward Halse.

"Note on the Occurrence of Mercury at Quindiú, Tolima, U. S. Colombia." By Mr. Edward Halse.

"Mining Explosives: Their Definition as Authorized under the Explosives Act, 1875." By Mr. A. C. Kayll.

"Miss-fires." By Mr. J. D. Kendall.

"Singareni Coal-field, Hyderabad, India." By Mr. J. P. Kirkup.

"Corliss-engined Fan at Seghill Colliery." By Mr. C. C. Leach.

"Historical Sketch of the Whitehaven Collieries." By Mr. R. W. Moore.

"Magnetic Declination and its Variations." By Prof. H. Stroud.

"Minerals and Mining in Tasmania." By Mr. A. P. Wilson.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, OXFORD, 1894.

The report of the proceedings of the Corresponding Societies' Committee of the British Association was read, and of Prof. J. H. Merivale, the delegate of the Institute, as follows:—

NEWCASTLE-UPON-TYNE,
AUGUST 25TH, 1894.

TO THE PRESIDENT AND COUNCIL OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

DEAR SIRS,

I went to Oxford on the 8th instant as the representative of the North of England Institute of Mining and Mechanical Engineers. Unfortunately, the sudden death of Mr. Scott called me home before the conclusion of the meeting, and I was therefore unable to attend the second conference of delegates and several of the sectional meetings. But through the courtesy of friends and a study of the accounts in the scientific papers I am able to make a full report.

The first conference of delegates of the corresponding societies was devoted to the consideration of local natural history museums, how the specimens may be best arranged, preserved, catalogued, and made generally more useful.

At the second meeting, the report of the committee on earth-tremors was discussed, more particularly with reference to Mr. Horace Darwin's bifilar pendulum. It would seem that the bifilar pendulum is admirably adapted for measuring the minute changes of level, which are perhaps the cause of some of the uneliminated errors in many astronomical and physical inquiries. Again, the bendings of the earth's crust by changes of barometric pressure, by the ebb and flow of the tides, etc., may be studied, as well as the long-period pulsations produced by violent earthquakes in almost any part of the world. It is not too much to expect, also, that in time we may be able to trace out and measure the slow secular movements of the earth's crust which, after the lapse of ages, become perceptible to the geologist; and that the vexed question of the origin of lake-basins may receive an answer that will remove this most debatable of subjects from the domain of controversy for ever.

There was also a discussion upon the report of the underground waters committee.

Several papers of interest were read in the various sections; among which may be mentioned a paper upon the "Chemistry of the Coal-formation," by Mr. J. W. Thomas, of Gloucester. The author said that the age of the coal and the physical conditions, such as the effect of water, heat, and pressure, should throw light upon the chemistry of coal-formation; but the coals in one coal-field are found under different physical and chemical conditions from those in another, and little evidence is obtained by comparison. The decomposition of peat and wood to-day teaches the chemistry of coal-formation. In both instances the woody fibre disappears first, leaving a residue richer in resinoids. The lignites of Bovey Tracey have, as in the case of decaying peat and wood, an excess of resinoid matters over the vegetation which formed them. Mr. Hutton found mineral resin in carboniferous coals, and others have done so since. Mr. Witham showed long ago, and much recent evidence proves, that conifers and other dicotyledons flourished during the Carboniferous period. Just as lime and other trees shed saccharine matter on the leaves and grass underneath, so it is probable that liquid, gummy, and resinous matters were showered from the forest vegetation during the Carboniferous and Tertiary periods. The chemical changes in coal-formation took place chiefly at and near the surface. In the formation of paraffin-shale and some Scotch cannels the woody fibre of the forest-growths was destroyed, little else but bituminous matters remaining. A resinous vegetation without much dicotyledonous trees, or, if with dicotyledons, considerable surface exposure and decomposition of the woody fibre, would produce rich bituminous coal, cannel, etc. A luxuriant resinous and dicotyledonous vegetation without much surface-decomposition probably gave rise to semi-bituminous, steam, and anthracite coal, assisted by heat and pressure. Further investigations are necessary, and in particular a study of the hygroscopicity of coal might throw considerable light on the spontaneous combustion of coal on board ships.

Dr. Haldane read a paper on "The Causes and Prevention of Suffocation in Mines," in which he described the practical importance of the investigation, and brought forward evidence that about 75 per cent. of the deaths after a large colliery explosion were due to suffocation. This was against the evidence generally given at inquests. At these inquiries about 70 per cent. of the deaths were attributed to injuries due to the force of the blast, and only about 30 per cent. to the suffocation by after-damp. He discussed the composition of the gases found in mines which caused death by suffocation, and remarked that he was very much surprised to find that articles on these gases in chemical books were of a slovenly

character. He distinguished between the qualities of fire-damp, black-damp, and white-damp. Fire-damp consisted for the most part of marsh gas, and it was only rarely that it played any part in suffocation, though there were instances of miners being rendered insensible by it. The popular idea was that black-damp was composed almost entirely of carbonic acid gas; but analyses showed that there was in it only about 10 per cent. of carbonic acid gas, and that the rest of it was nitrogen. He thought that the deadly qualities of black-damp were due, not to the presence in it of carbonic acid gas, but to the absence of oxygen. This had been practically demonstrated in the laboratory, and Dr. Haldane showed one or two experiments and a number of diagrams, on which were represented the positions of bodies found after explosions in mines, proving that many of the men had, after the explosion, travelled long distances, to be at last overcome by the fumes of the after-damp. White-damp got its name from the fact that it frequently presented the appearance of white steam. This was frequently formed from the combustion of gunpowder, and he referred in this connexion to an accident which occurred some years ago on the shores of Loch Fyne, where a party of excursionists going into a quarry after an explosion were overcome by the fumes of the products of combustion. He had analysed white-damp, and found that the deadly components in it were carbonic oxide and sulphuretted hydrogen. The practical question was, could any means be devised whereby the miners who were not killed by the blast of an explosion could be kept alive for an hour or two, so as to give them a chance of getting into the main ways, which might still have sufficient oxygen in them to maintain life? The lecturer exhibited a little box which he had devised, the principal part of which consisted of a cylinder of compressed oxygen, an apparatus being attached to it by which the miners, under the circumstances already referred to, might breathe oxygen, and be thus saved from the effects of the choke-damp.

Dr. Shaw Lyttle, in his paper on "The Effects of After-damp," said that he descended with the third exploring party after the explosion at the Albion colliery, and was engaged in ministering to the needs of the survivors. He described the exact localities in which the survivors were found, in relation to the places where they were working at the time of the explosion, and also the symptoms which they exhibited. Along the Cilfynydd level, the bodies were much burned and mutilated where the largest fall of roof had occurred. One survivor in the dip seemed quite dazed; he knew no one, could not articulate, and did not appear to comprehend why a stimulant was put to his mouth. Some men were lying down and had the appearance of suffering from an ordinary epileptic attack; they were frothing at the mouth, and one was tossing violently from side to side and striking his head against the ground. One was sitting up and groaning. Only two or three were able to swallow the stimulant offered them. In the Pantddu dip, thirty bodies were found, all asphyxiated. In Dudson's dip, off the Grover level, thirty-seven bodies of men were found. Of seventy bodies examined, eleven died immediately from burns; twenty-two from asphyxia; nineteen from burns and asphyxia, but who, without after-damp, would probably have succumbed subsequently; six from violence irrespective of burns; twelve from violence and burns, but in some of these asphyxia may have had a part. Dr. Lyttle added the observations of rescuers. Some felt smarting of the eyes and attributed it to dust. Some did not perceive any smell of burning, others did; one said of wool, another of matches, a third said it was "sulphury." The survivors in the Grover level, according to one rescuer, drank water greedily, but when brought out of the pit they seemed to lose consciousness, and could not answer questions so readily as before.

Professor Kennedy devoted his presidential address, in the mechanical section to "The Critical Side of Mechanical Training." He considered that in cases where

a university or university college takes in hand the preparation of engineers (and he hopes that such cases will grow in number), they should provide for them special training in mathematics, and probably also in physics, distinct from the general training in these subjects most suitable for degrees.

Mr. R. H. Hooker read a paper on "The Relation between Wages and the Numbers employed in the Coal-mining Industry," and said that the influence of wages in attracting labour to an industry was best shown by means of a diagram, and the industry concerning which we possessed the most trustworthy statistics of wages and of the numbers employed over a series of years was undoubtedly coal-mining. The data concerning this occupation had accordingly been plotted on a diagram, in which one line represented the course of wages from 1871-91 in the county of Durham (according to the evidence of Mr. Lindsay Wood before the Labour Commission), while another line showed the number of persons employed in coal-mining in the same county (taken from the annual reports of H.M. Inspectors of Mines). The wages were expressed in percentages above or below the rate paid in 1871. The correspondence of the two curves was very apparent, and, judging by the magnitude of the fluctuations, it would seem that the variations in the number of the employés must be attributed almost entirely to the changes in wages. Especially the very large increase of miners in 1872-74 and 1889-91 could hardly be ascribed to any other cause than to the attraction of the great rise in wages at those periods. It must be remembered that the coal-mining industry was in many respects peculiar, the organisation of the men was very complete, and the principle of the sliding scale was everywhere in force, even in those districts where a scale did not actually determine the wages. These latter being then dependent on prices, employers could not lower their rate of pay when the supply of labour was unusually large, nor could they raise the remuneration unless there was a corresponding change in the price of coal. It would seem, then, that the numbers depended on the wages. It did not follow that this condition prevailed in every occupation, but it was probable that, according as the organization of the men in any industry was more complete, there was a greater tendency in that industry for the numbers employed to follow the wage.

Yours faithfully,

JOHN H. MERIVALE.

DISCUSSION ON DR. P. PHILLIPS BEDSON AND MR. W. McCONNELL, JUN.'S, PAPERS ON "A CONTRIBUTION TO OUR KNOWLEDGE OF COAL-DUST.—PARTS II. AND III."*

The PRESIDENT said that the Institute owed a debt of gratitude to Dr. Bedson and Mr. McConnell for the pains which they had taken to instruct the members on this important subject.

Dr. BEDSON said that there was only one point in connexion with the subject on which he would like to say a word. There was perhaps to some minds very little that was novel in the fact that coal-dust should resemble coal so nearly, and many minds in approaching the subject seemed to think that as coal—as proved by Messrs. Thomas and Meyer—contained combustible gases, coal-dust would do so too. But to

* *Trans. Fed. Inst.*, vol. vii., pages 27 and 32.

him it appeared necessary, although one might assume that coal-dust would resemble coal, to establish this by experiments ; and the attitude of mind which regarded these contributions as foregone conclusions from the knowledge they already had of coal, was something of the same kind as that of the philosopher who forms a system of the universe by sitting quietly in his study. He wished simply to make these remarks in justification of some of the criticisms which had been made on the work covered by these papers. To his mind it was absolutely essential to demonstrate that coal-dust did hold enclosed gases. The experiments that had been recorded, demonstrated that certain coal-dusts yielded no inflammable gases, while others were remarkable for the high proportion which they contained. In connexion with this work he had been recently studying the report of Mr. Henry Hall's experiments, made for the Royal Commission on Explosions from Coal-Dust in Mines, and he expected to have obtained from it some light as to the behaviour of coal-dusts. He found that Mr. Hall's investigations included coal-dust from the same seams and representing the same dusts as those which Mr. McConnell and himself had submitted to exhaustive treatment. Mr. Hall succeeded in obtaining an explosion with almost every coal-dust investigated, but what he (Prof. Bedson) hoped to find in Mr. Hall's experiments was an indication that coal-dusts like those of the hutton and low main seams in Durham and Northumberland, which they had found to be remarkable for the high proportion of combustible gases they enclosed, would differ from such dusts as those obtained from Brancepeth, and other dusts which were remarkable for the complete absence of these inflammable gases.

The PRESIDENT asked what was the lowest temperature to which coal-dust had been submitted, and gas found to exude?

Dr. BEDSON replied that the lowest was 86 degs. Fahr., but all of his experiments were of course under reduced pressure, practically in a vacuum.

The PRESIDENT remarked that the temperature in deep mines would probably be about 86 degs. Fahr. or less.

The discussion was then closed.

Mr. SIMON TATE read the following paper on "Saving of Life from After-damp, Smoke, or Fumes in Mines":—

SAVING OF LIFE FROM AFTER-DAMP, SMOKE, OR FUMES IN MINES.

BY SIMON TATE.

It has been the writer's painful duty on several occasions to be one of an exploring party in a coal-mine after an explosion. Every explosion makes one acquainted with the fact that many, if not the greater, portion of the lives sacrificed are not lost by the force and violence of the explosion, or by direct contact with the flames or heat, but from inhaling the deadly after-damp. The proportion of deaths due to this latter cause is said to exceed twice the number of those killed by the force or heat of the explosion.

At the recent explosion at the Albion colliery the proportion of deaths due, altogether or partly, to the inhaling of the after-damp was stated by Dr. J. Shaw Little to be 58 per cent., but he had only examined 70 bodies. He also stated that 30 bodies were found in one place and 37 in another, all of which deaths were caused by the after-damp.

If the workmen left alive and uninjured by the force of an explosion could be rescued, colliery explosions would be deprived of some of their most terrible consequences, and the number of lives lost would be considerably diminished.

The writer has often thought that the very means adopted to reach the imprisoned men after a mine explosion has literally shortened their lives by forcing upon them the silent and deadly after-damp.

There have been frequent instances after an explosion where workmen have been left alive and uninjured in remote portions of the mine, often so far distant that they were scarcely aware that anything serious had occurred, except from hearing a slight rumbling sound, or noticing an alteration or cessation of the air-current; yet they have, after hours and even days of anguish and uncertainty, at last died owing to the after-damp penetrating the portion of the mine in which they were.

A case is recorded where a workman was in a mine in which an explosion occurred, but at such a distance from the direct effects of the explosion as to be uninjured. He took refuge between two trap-doors, which he endeavoured to make air-tight. He so far succeeded that he

lived for a considerable period after every one else in that portion of the mine had succumbed. He left a record in chalk upon one of the doors, showing that he was able to withstand the effects of the after-damp for a considerable length of time, and had there not been a "standing fire," which presumably necessitated the sealing-up of the mine, this man would in all probability have been rescued alive.

These and other considerations have led the writer to devise some practical means of overcoming this serious danger. He is aware that it has been suggested to have *ports-d'abris* (*i.e.*, safety-cabins, hermetically sealed, but connected by ranges of pipes, telephonic communication, etc., with the surface, etc.). In many cases the use of such contrivances are, to say the least, impracticable, because the out-bye roads and shafts are completely wrecked. These facts, together with the great cost of their erection and maintenance is undoubtedly the reason why similar contrivances have not been adopted.

The writer's idea is that any person who may be situated in a portion of a mine at the time of an accident, either from explosion or fire, and whose passage to the shaft or outlet is cut off either by after-damp or smoke, should have a means provided by which he can isolate or separate the district, or a portion of it, from the other portions of the mine affected by the accident. To do this the writer proposes that close-fitting doors should be placed in a suitable position upon the intake and return air-ways, and also that relief-doors or slides should be placed in the holings between the intake and return air-ways immediately on the out-bye side of the before-mentioned doors.

The accompanying and somewhat ideal plan, Fig. 1 (Plate XIII.), illustrates the writer's suggestion:—A and B represent districts worked by the bord-and-pillar system, C and E long-wall districts, and F and G are wide-wall and double-stall districts respectively. In cases of emergency, any person finding he was in danger of losing his life by foul air penetrating into that portion of the mine could immediately establish communications between the intake and return air-ways (on the out-bye side of whatever position the doors might be placed) by opening the slides of the doors *d* fixed in the stentons or holings.

It will be observed that any of these districts can be completely isolated from the other districts, by closing doors fixed at the points D. Any person on the in-bye side of such doors when closed would then be entirely separated from the dangerous atmosphere resulting from an explosion or fire, and he would be able to exist for a considerable period upon the air confined on the in-bye side of these closed doors.

The panel system of working offers peculiar facilities for carrying out the writer's suggestion, and faults or troubles crossing the airways could be utilized as barriers to isolate a portion of the mine. In long-wall workings, a range of gateways could be carefully and closely stowed, and thus form a barrier without loosing or leaving any coal. (See E, Fig. 1, Plate XIII.) In fact there is no practical difficulty to prevent its adoption under any of the more general methods of working mines.

Some of the advantages that would probably accrue by the adoption of the proposed system may be enumerated as follows :—

(*a*) The certainty of the persons so isolated not being reached by the after-damp or smoke for a length of time after the explosion or fire, sufficient in many cases to allow of their rescue.

(*b*) The restoration of air-currents and the clearing away of the after-damp or smoke would be facilitated by the shortened length of air-ways.

(*c*) The early ascertainment that persons had survived the force of the explosion (shown by the doors being closed) and were probably still alive on the in-bye side of the doors, waiting to be rescued.

Even if it be thought unnecessary to adopt this plan in its entirety, it might be desirable that favourable positions should be pointed out to the workmen by the officials of the mine, and that material should be conveniently placed for fixing stoppings in the intake and return air-ways, so as to prevent the after-damp or smoke reaching or penetrating any isolated area.

Mr. A. L. Steavenson said that they all knew the old proverb that "Prevention was better than cure," and if they were not able to prevent explosions, the next best thing was to minimize the effects as much as possible, and Mr. Tate had made valuable suggestions with that object. Coming from such a practical man as Mr. Tate, his proposals demanded their very serious consideration. No doubt Mr. Tate was well aware as to the difficulties of applying his proposals ; one of the first difficulties was that after an explosion all the stoppings were blown out and the roof fallen down, everything was in such a condition that, even if they got to his proposed safety-doors, they would not move. But the great difficulty would be in getting to the places, and travelling over falls, etc., so as to reach them. Another point was that most of the mines in the

North of England were old mines, and it would be difficult to apply the system except to new portions of the mine. He would not like at present to express an opinion on the subject. Refuge-places had been frequently recommended, and Col. Shakspeare had recommended refuges communicating with the surface by means of boreholes.

The PRESIDENT said that within his own experience he remembered life being saved by a workman in a confined part of the mine erecting a stopping on his own responsibility, at the end of the place in which he was working—100 feet away. He (the President) agreed with Mr. Steavenson that Mr. Tate's proposals were especially applicable to new mines. It was very useful to know Mr. Tate's views on a question of this kind, but he did not know that he could quite follow him further than to think that a workman might do something intelligently to assist in saving life in cases of emergency. A knowledge of the mine in such instances was also essential, so as to enable him to use proper means with safety to himself.

Mr F. BERKLEY thought that if the force of the explosion was sufficient to break down the stoppings and doors, it would be sufficient to kill the workmen, in which case the proposed method would be useless; he thought, however, that most collieries would have some districts which would allow of Mr. Tate's proposals being adopted, either by making use of the restricted workings, places driven through a fault, or by working in panels.

Mr. W. C. BLACKETT said that if an explosion spread through a mine and left some districts still and quiet, so as not to affect the workmen, they would not know that anything serious had occurred. Mr. Tate himself had recognized this fact in his paper. Something had occurred perhaps which was only sufficient to excite their curiosity, they were the least alarmed people in the pit, but thinking there might be something wrong they would perhaps go outbye to see what was the matter, and if they went sufficiently far to meet the after-damp they might fall victims to it. Still, there was the fact that some people were aware of what had occurred, and were able to get to certain portions of the mine, and if in such cases they had the wit to put up the safety-doors, it was quite possible that there would be sufficient air in such districts as Mr. Tate had sketched, if a large quantity of gas were not given off by the seam, to preserve the lives of 15 or 16 men for a week. There were few seams, however, that would not give off a large quantity of some kind of gas, and this would tend to diminish the length of time, although in many cases it might run into days.

Mr. J. M. Liddell suggested the desirability of having telephonic communication from the surface to the different parts of the workings as a means of safety. This communication was desirable, so that the men in a given district might be warned of the danger which had arisen from an explosion in another district, and that when it was discovered they might be prevented from becoming struck with panic, and running into the after-damp. If telephonic communication could be made it would have a reassuring effect, and it would be possible to warn the men in all districts before the after-damp reached them, and to give them proper instructions. There was perhaps some little difficulty with regard to the question of carrying the wires so as to avoid breakage, in case of an explosion, but he thought that this difficulty might be overcome.

Mr. C. J. Murton said he foresaw a difficulty in not being able to ascertain with certainty the part of the mine affected by the explosion. If the wrong doors were closed men might be imprisoned who were really not otherwise in danger.

Mr. Joseph Routledge said that in his younger days he had been down the mine during two explosions, and he had found that wherever an explosion took place the force came back into the place it had left. The explosion took place, went as far as the force would allow, and this was followed by a movement or "back-lash" towards the place of origin.

The President said that every means should be adopted even to save a single life. At present he could not say more than that it was most desirable that means should be adopted by which lives might be saved by the intelligence of the people working in the district.

Mr. Simon Tate said that if an explosion occurred and reached a given district, it was not much use trying to save the men there afterwards, as they would probably all be killed. He thought there were very few pits that had not new districts where the system could be adopted, but he agreed that it would be difficult to apply it to the case of broken or pillar workings, unless there were troubles or faults which isolated a portion of them. One speaker remarked that men rushed out at the first alarm and were lost, but his (Mr. Tate's) experience was that very few did that. In three different explosions that he had known, 13, 26, and 30 men, respectively, came so far out and met the fumes, and then went back to try and escape by the return air-ways. Workmen were found in the return air-ways who had tried to get out in various ways. They only wanted to know how to isolate themselves, and they would have done it, they had not lost their self-control. In one case, as soon as they heard the sound of the explosion 3 rushed out, but 13 workmen remained until

they got the deputy to lead them, and by that time the air had taken another course, cleared a portion of the district, and they got safe to the shaft.

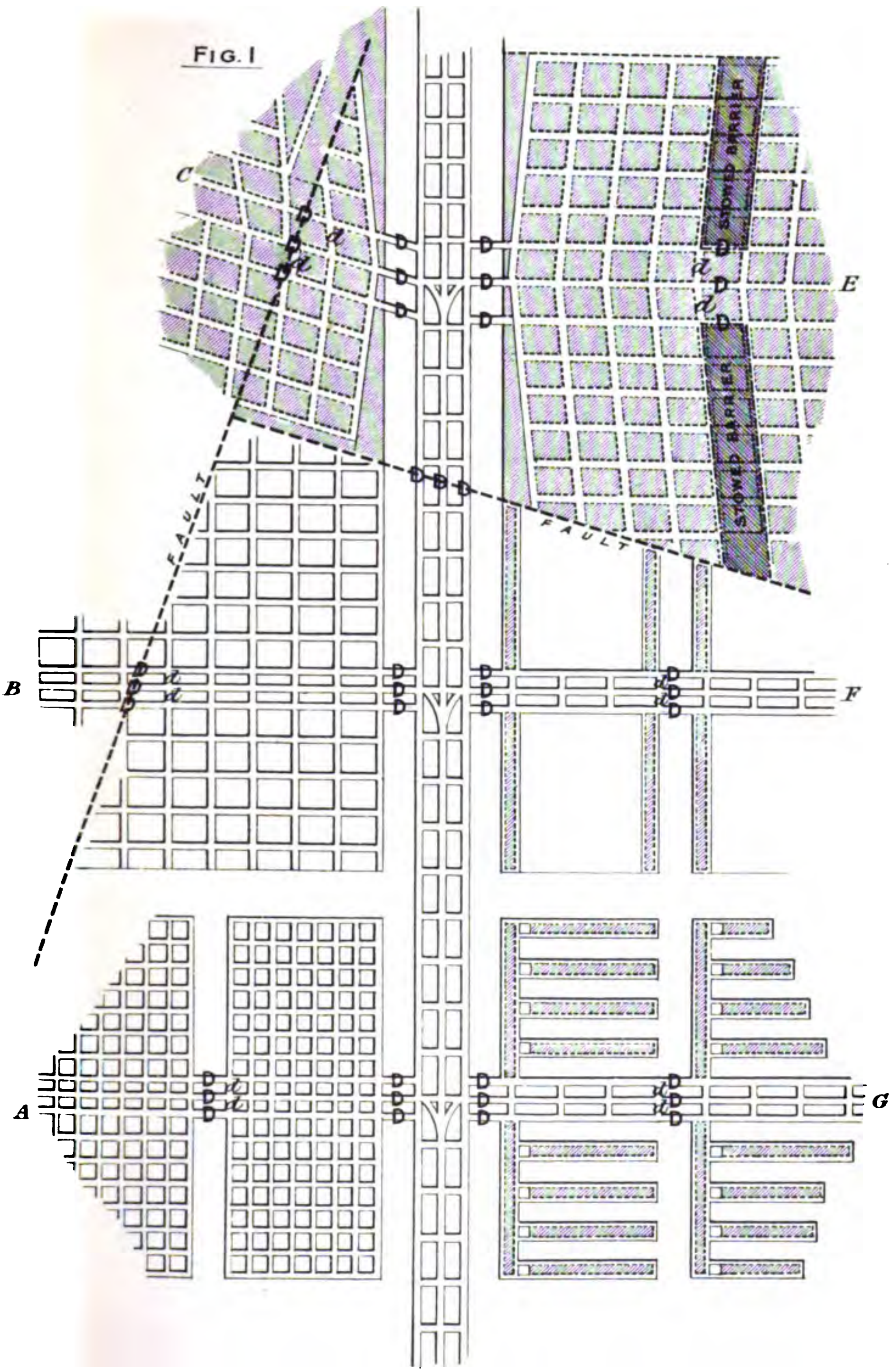
Mr. A. L. STEAVENSON asked whether Mr. Tate had applied his suggestions practically?

Mr. TATE said that he had not, but he had not put his opinions on paper without due consideration, and he thought it better to bring the matter forward at once rather than wait for an explosion.

The PRESIDENT proposed a vote of thanks to Mr. Tate for his paper, which was agreed to, and the discussion was then adjourned.

The following paper by Mr. E. P. Wood on the "British Guiana Gold-fields" was then taken as read:—

To illustrate Mr. S. Tate's Paper on "Saving of Life from After-damp, Smoke or Fumes in Mines."



BRITISH GUIANA GOLD-FIELDS.

By E. P. WOOD, Commissioner of Mines.

So little is known of the whereabouts of British Guiana that perhaps the writer may explain that it lies on the northern coast of South America, and not on the West Coast of Africa, as so many people think.

British Guiana is readily reached from Southampton by one of the Royal Mail line of steamers; in about twelve days the traveller arrives at Barbados, where he tranships into a smaller steamer, and thirty-six hours later he lands at Georgetown, the capital town of British Guiana (or Demerara as it used to be called).

The best time of the year to arrive in British Guiana is about October; but with the exception of July, August, and September, there is very little difference in the climate all the year round.

A large area of the coastland is occupied by sugar-planters, and the gold-regions are found some distance inland.

The climate resembles that of Northern Queensland, being too hot for hard manual work by Europeans, but not too hot for prospecting or for superintending the work afterwards. The heat in the shade seldom exceeds 90 degs., but it is a very exhausting heat, and equal, in the writer's opinion, to 120 degs. in other countries. There are two wet seasons in the year, for two months each, about Christmas and Midsummer. The rainfall may be taken at about 110 inches a year.

Gold is being found in British Guiana up the several rivers at a distance of from 100 miles to 300 miles from Georgetown. The richest district is upon the Potaro river, a branch of the Essequebo. In the North-west district, gold is being obtained from the Cuyuni, Mazaruni, and Demerara rivers. The return from the various districts during the last two years for placer-washing, was :—

	1892-93.				1893-94.		
Districts.	Ounces.	Dwts.	Grs.		Ounces.	Dwts.	Grs.
Essequebo	68,033	6	8	...	72,287	7	10
North-west	32,905	1	8	...	31,837	17	11
Cuyuni	20,712	1	8	...	24,978	0	1
Mazaruni	12,216	5	3	...	9,418	17	2
Demerara	257	13	20	...	5	14	14
Totals	134,124	7	23	...	138,527	16	14

The following statement shows the amount of gold obtained in the colony during the below-mentioned years:—

Years.	Gold. Ounces.	Dwts.	Grs.	Years.	Gold. Ounces.	Dwts.	Grs.
1884	250	0	0	1889-90 ...	32,332	16	5
1885	939	0	0	1890-91 ...	66,864	4	21
1886	6,518	1	12	1891-92 ...	110,555	12	5
1887	10,986	14	0	1892-93 ...	134,124	7	23
1888-89 ...	20,216	1	8	1893-94 ...	138,527	16	14

The exports of gold, and its declared value, during the years ending March 31st, 1892-93 and 1893-94 were as follows:—

Years.	Gold Exported. Ounces.	Dwts.	Grs.		Values Dollars.	Cents.
1893-94	137,629	2	18	...	2,451,408	01
1892-93	133,146	14	4	...	2,366,100	51
Increase	4,482	8	14	...	85,307	50

The country is all dense forest-land; and, as no roads have been formed, the only way of getting to the different places is by boat, the rivers all being navigable for great distances inland. People going gold-digging either buy or hire a boat sufficiently large to carry, say, twelve or fourteen workmen and three months' provisions. They then engage and register a certain number of labourers. There are steamers leaving once a week for the North-west district, and every day for Bartica, a settlement at the junction of the three rivers—Cuyuni, Mazaruni, and Essequebo. Thence you have to take to your boat and paddle to your destination. Flooded rivers do not stop the boats from going up, except on very rare occasions.

The connexion of the Demerara river with the Essequebo above the falls by the Demerara-Essequebo Railway, will avoid the danger of boat accidents and the difficulty of passing the rapids of the Essequebo river. It is important that this line of railway should be completed with as little delay as possible, and when it is finished the gold-output from this district of the colony will be considerably increased.

All food, tools, etc., can be obtained in Georgetown at reasonable rates. Boats cost about £25 each. A labourer's wage is 2s. 8d. per day and his food costs about 10d. per day.

The royalty on all gold obtained in the colony is 3s. 9d. per ounce, and must be paid to the Colonial Treasury at Georgetown before the gold can be sold.

A prospecting licence costs 2s. 1d. per month; for every grant of a mining claim 8s. 4d. per month, and for every grant of a placer claim 4s. 2d. per month.

The area of each alluvial working claim is 1,500 by 500 feet, and as a rule the depth of stripping is about 4 feet and the wash about 2 feet thick. The claims are all heavily timbered. Water is fairly plentiful, but has very little fall, as the country is somewhat flat. In many claims pumps might be used, instead of bailing with buckets as at present.

In one or two instances rich placer-claims have been re-worked with profitable results.

Reef-claims are not being worked at present, but the Kanaimapoo Company has erected crushing machinery. The quartz is very rich, many surface samples assaying 50 ounces per ton; and though these may have been selected pieces, yet, where there is no visible gold, it often yields 8 to 10 ounces per ton. The reefs are of all sorts and sizes, the quartz being very friable, but so little has been done as yet that one cannot form a very correct judgment as to their permanency. There may be an exceedingly rich reefing district, but the chief thing needed is workmen that understand mining. The labourers require to be educated in underground work, but there is no reason why they should not make good miners eventually.

During the past 12 months, several parties have been prospecting for and locating mining claims. The writer believes that the future success of the colony as a gold-producing country will be dependent upon quartz-mining rather than upon the working of placer-deposits.

The number of claims located during the years 1892-93 and 1893-94 has been as follows:—

	1892-93.	1893-94.
Placer	1,122 ...	1,425
Mining	48 ...	751

During the years 1893-94 3,333 prospecting licences were issued, and 105 second authorities were given out as licences.

Timber for mining purposes grows on every claim, and each claim-holder is entitled to cut what he requires free. If more is required than his claim can yield, a wood-cutting grant can be obtained at a small rental.

At present there are very few white men working, nearly all the exploring parties being composed of blacks, financed by store-keepers and others in Georgetown. This mode of working must very shortly cease, as the gold in many cases does not find its way to the owners.

A few white miners are now coming into the colony and appear to be able to stand the climate, but unless they come in larger numbers there can be no material increase in the production of gold.

The labourers are African blacks, the descendants of the slaves of former years. But their labour cannot be properly applied without the superintendence of white miners. The following statement shows the number of gold-mining labourers registered monthly during the year 1893-94 :—

1893.	Baramanni.	Bartica.	Georgetown.	Koriabo.	Totals.
April ...	—	317	968	—	1,285
May ...	48	370	917	158	1,493
June ...	43	676	858	153	1,730
July ...	52	555	1,132	360	2,099
August	46	1,046	1,547	73	2,712
September	61	449	975	279	1,764
October	62	278	661	127	1,128
November	36	297	514	139	986
December	33	85	220	102	440
1894.					
January	4	1,281	1,520	204	3,009
February	181	438	632	306	1,557
March ...	83	415	602	168	1,268
Totals	649	6,207	10,546	2,069	19,471

It must, however, be noted that in many cases labourers have registered themselves several times during the year, so that the figures recorded in the preceding table are somewhat higher than the actual number of workmen employed.

The number of gold-mining labourers registered during a few recent years is as follows :—

Years.	No. of Workmen.	Years.	No. of Workmen.
1888-89	4,765	1891-92	22,298
1889-90	7,224	1892-93	22,957
1890-91	15,622	1893-94	19,471

There was a decrease of 3,486 in the number of gold-mining labourers registered during 1893-94, as compared with 1892-93, but this decrease may be accounted for by the fact that fewer people are embarking in the gold industry, owing to the dishonesty that is practised at the diggings.

The value of gold produced per labourer during the last two years was as follow :—

Years.	No. of Workmen Registered.	Value of Gold Produced. Dollars.	Cents.	Average per Workman. Dollars.	Cents.
1892-93	22,957	2,414,239	16	105	16
1893-94	19,471	2,493,500	93	122	92

Every day proves that British Guiana is an extraordinarily rich country, and that it simply requires development by capital.

It may be asked how it is that the production of gold has not increased at a greater rate than it has, but the answer to that question is: that the number of workmen was less last year than it was the year before.

There is not the slightest doubt that in years to come there will be a very large output of gold from British Guiana.

Copper and silver have been found in the colony, but there is nothing as yet to prove that they exist in payable quantities.

Several diamonds have been found in panning-off the gold at the end of a day's work, and, considering that they are found under such circumstances, a diamond miner would be of opinion that they must exist in larger quantities. The writer has no doubt that diamond mining would pay, if a small pulsating-machine were tried. There is little chance of a diamond stopping in the box in sluicing, and still less chance of its being discovered in panning-off. Many of the labourers employed, never having seen a diamond in its natural state, are only attracted to it by the peculiarity of its shape.

Mr. Bennett H. Brough regretted that the author had not given some historical information, so as to render his valuable paper thoroughly complete. Few countries presented greater historical interest. From the time of the discovery of Guiana, four hundred years ago, the imaginations of the Spanish settlers were fired by the accounts given by the Indians of the abundance of gold in the interior. Many expeditions were fitted out to seek for these gold deposits, the best known being that of Sir Walter Raleigh, who started in 1595 in search of "Manoa, the imperial city of Guiana, which the Spaniards call El Dorado." On his return he published an account of his adventures, a fascinating volume, bearing a strong family resemblance to the mine prospectuses of modern times. Much money and many lives were expended in this expedition, and the existence of gold in Guiana has since invariably been regarded with incredulity. It was thought to be an accompaniment of an age of romance, and one frequently came across allusions to "the El Dorado myth." The startling figures given by Mr. Wood, showing the rapid annual increase in the gold production from 250 ounces in 1884 to 138,527 ounces in 1893-94 undoubtedly proved, however, the accuracy of Sir Walter Raleigh's belief in the gold resources of Guiana. Sir Walter Raleigh brought back with him specimens of ore, some of which was, he

said, "as rich as the earth yieldeth any." He was, however, not able to conduct any mining operations, his explanation being as follows:—

We were not able to tarry and search the hills, so we had neither pioneers, bars, sledges, nor wedges of iron, to break the ground, without which there is no working in mines: but we saw all over the hills with stones of the colour of gold and silver, and we tried them to be no marquesite, and therefore such as the Spaniards call El Madre del Oro, which is an undoubted assurance of the general abundance; and myself saw the outside of many mines of the white spar, which I know to be the same that all covet in this world.

Sir Walter Raleigh, it thus appeared, was aware of the existence of quartz reefs. The workings of his date appeared, however, to be alluvial. His description was as follows:—

I after asked the manner how the Epuremei wrought these plates of gold, and how they could melt it out of the stone; he told me that most of the gold which they made in plates and images was not severed from the stone, but that on the lake of Manoa, and in a multitude of other rivers, they gathered it in grains of perfect gold, and in pieces as big as small stones, and that they put to it a part of copper, otherwise they could not work it, and that they used a great earthen pot with holes round about it, and when they had mingled the gold and copper together, they fastened canes to the holes, and so with the breath of men they increased the fire until the metal ran, and then they cast it into moulds of stone and clay, and so make those plates and images.

The meeting was then closed.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,
HELD IN THE ROOMS OF THE CHRISTIAN INSTITUTE, GLASGOW,
OCTOBER, 10TH, 1894.

MR. GEORGE A. MITCHELL, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected by ballot :—

FEDERATED MEMBERS—
THOMAS BOUSFIELD, Wallsend, New South Wales.
CHARLES E. BOWRON, Tracy City, Tennessee, U.S.A.
JAMES O. BROWN, 19, Waterloo Street, Glasgow.
E. H. A. COHEN, Moodie's Pioneer Gold Mine, Barberton, Transvaal.
JAMES JOHNSTONE, Belhaven Road, Wishaw.
WILLIAM JOHNSTONE, Brighton Place, Polmont Station.
HENRY KENNEDY, Fauldhouse.
WILLIAM M. KILPATRICK, Struther Colliery, Larkhall.
RANDOLPH GORDON ERSKINE WEMYSS, Wemyss Castle, Fifeshire.

NON-FEDERATED MEMBER—
WILLIAM B. SPARROW, 39, Clydesdale, Wishaw.

DISCUSSION ON MR. J. T. FORGIE'S PAPER ON "THE ELECTRIC-POWER PLANT AT DUMBRECK COLLIERY, KILSYTH."*

Mr. FORGIE said that the cables had been in use for two years, and they had not been damaged by the glands. He did not know that he had fairly laid himself open to Mr. Rowan's criticisms. He never meant to compare the cost of electric with band-rope haulage, as he believed that band-rope haulage could be fitted up at less cost than the electric plant. Nevertheless he did not believe that the band-rope haulage could be fitted up for the amount mentioned by Mr. Rowan, who, he thought, had underestimated all his items. In his paper he had laid down several advantages which were got from the electric haulage, and he thought that these, especially in deep shafts, would overcome any extra cost as compared with the band-rope. Mr. Rowan spoke of using band-ropes for two and a half years.

* *Trans. Fed. Inst.*, vol. vii., pages 121, 344, and 584.

He had had considerable experience of band-ropes at the same depth as that mentioned by Mr. Rowan, and hauling about the same number of tons, and he considered that the ropes did well if they lasted for twelve months. In deep pits (say 1,500 feet) the cost of the band-rope became a considerable burden, and there was extra wear-and-tear connected with it. From every point of view he thought that the comparison was in favour of electric haulage.

Mr. A. M. Grant (Kilmarnock) said that it seemed to him to be quite legitimate for Mr. Rowan to have introduced a comparison between the band-rope and electric haulage. He agreed with Mr. Forgie that Mr. Rowan's figures as to the cost of a band-rope were considerably underestimated, but if they took their rope from the surface to the far end they could do without the band-rope. By that means they would add considerably to the life and work of the rope.

The President—Supposing that you had six haulages down below, would you take six ropes down the shaft ?

Mr. Grant answered in the affirmative.

The President said that six ropes in the shaft would considerably increase the danger from that source. Most managers would agree that it would be an awkward experiment to make, and that it would be better to adopt the band-rope than work all the ropes down the shaft.

Mr. Forgie said there was one point he wished to make a little clearer. When he admitted that band-rope haulage could be erected at a cheaper rate than electric haulage he only meant the initial cost. He would not admit that the ultimate cost would be less than that of the electric haulage. In fact, his experience had been the very opposite.

The President said he thought that it would be a pity if they allowed the discussion to close without something more being said on the subject of the comparison between band-rope and electric transmission of power. He thought that it would be unfortunate if Mr. Rowan's figures were taken as altogether accurate. He believed that Mr. Rowan had exaggerated the cost of the electric arrangement and cheapened that of the band-rope. For instance, Mr. Forgie would be able to tell if a constant attendant was required for the dynamo.

Mr. Forgie said that the man in charge had five or six other engines to attend to.

The President said that Mr. Rowan charged an engineman for the electric and none for the band-rope plant, while probably there was as much attention required in the one case as in the other.

Mr. FORGIE said that at Bothwell pit there was a workman specially employed in attending to the band-rope plant on the surface; while only one workman attended to the electric plant and the other engines on the surface, and one workman attended to the motor and haulage plant in the mine.

The PRESIDENT asked, if the haulage was worked with friction-clutches, could not the bottomer look after the motor as in the case of the band-rope?

Mr FORGIE replied that the motor required to be closed so as to keep it in order, and it was placed at a distance from the bottomer, requiring one workman to attend to it. It was difficult to estimate how much more expense there was connected with the electric plant than with the band-rope, but there was no doubt more expense.

The PRESIDENT said that the electric plant could develop 50 horse-power, while for haulage alone, 25 horse-power would probably have been sufficient. He thought that the yearly cost of the electric plant for haulage might be reckoned as follows:—Supposing the first cost of the electric plant was £700, 10 per cent. on that was £70, the attendance on motor and dynamo he put at £80, making a total of £150. He thought that Mr Rowan had rather over-stated the life of the band-rope, and that it would not last for more than twelve months. Supposing they took £100 per year, as the cost of band-ropes, and £45 for an attendant, that made £145 for the wire rope against £150 for the electric plant—practically the same, whilst the electric plant could be used for pumping, etc. In the present case, Mr Forgie had adopted the system best suited for his wants, and there was no system of band-ropes that could have accomplished it. He might have done it by means of compressed air, but that would have been more expensive, and the upkeep would not have been less than that of the electrical installation.

Mr. GRANT said he admitted the President's argument as to the danger of multiplying the number of band-ropes in the shaft. However, he did not think the danger was altogether so excessive as he assumed, because if they had five or six roads underground worked with one band-rope, they had 60 horse-power going through it, and it would only last six months, whereas in the way he suggested, they would probably only transmit 10 horse power each, and would last for two or three years or longer. The general experience was that a haulage rope should last from two to three years. It was perhaps hardly fair to make a comparison between band-rope and electric haulage in discussing this paper, but it was an interesting subject and should be thrashed out.

Mr. FORGIE thought that it was perfectly legitimate to make a comparison between band-ropes and electric haulage, but what he felt was that a comparison of the initial cost was not altogether fair. He had pointed out in his paper the advantages and disadvantges of the one and the other, and he thought that the advantages of the electric-power plant had never been better proved than during the last three months when the workmen were on strike, during which they had been able to keep three pumps going with the least posssible power on the surface. If they had had rope transmission they would have had miles of haulage-ropes running, for the purpose of pumping a few gallons of water.

The PRESIDENT, in closing the discussion, said that most people had been afraid of electricity under the impression that it might be liable to break down and entail a heavy annual upkeep. He thought that they need not now have any fear as to trying electric power, for Mr. Forgie had shown that the annual upkeep was no greater than under any other system. He moved a vote of thanks to Mr. Forgie for his excellent paper, which was heartily given.

DISCUSSION ON MR. R. FISHER'S PAPER ON "THE COAL-FIELDS OF LABUAN, BORNEO."*

Mr. GRANT asked whether there was any antimony in Labuan?

The PRESIDENT stated that perhaps Mr. Fisher would answer this question at the next meeting.

The discussion was adjourned.

Mr. ROSS read the following paper on the "Ross Rock-drill":—

* *Trans. Fed. Inst.*, vol. vii., page 587.

THE ROSS ROCK-DRILL.

By J. MACEWAN ROSS.

The Ross rock-drill is a departure in principle and design from the ordinary rock-drills at present in use.

An American publication states "that the percussive rock-drill has been invented and developed within the latter half-century." It also goes on to say that "it is distinctly an American invention, though claims are sometimes made that it had its origin in France and Germany. Rock excavations were carried on even before the discovery of America, and it is easy to understand that those who were engaged in removing rock would look for some means by which a hole might be drilled with greater rapidity than by striking a piece of steel with a hammer.

In 1683, a drop drilling-machine was used in Germany, and "with ten blows it would sink a hole 1½ inches deep and about 8 inches in diameter."

Mr. G. G. André states concisely the requirements of a good rock-drill as follows:—*

1. A machine rock-drill shall be simple in construction and strong in every part.
2. It shall consist of few parts, and especially of few moving parts.
3. It shall be as light in weight as it can be made, consistent with the first condition.
4. It shall occupy but little space.
5. The striking part shall be relatively of great weight, and it shall strike the rock directly.
6. No other part than the piston shall be exposed to violent shocks.
7. The piston shall be capable of working with a variable length of stroke.
8. The sudden removal of the resistance shall not be liable to cause injury to any part.
9. The rotary motion of the drill shall take place automatically.
10. The feed, if automatic, shall be regulated by the advance of the piston at each stroke.
11. The machine shall be capable of working with a moderate degree of pressure.
12. It shall be capable of being readily taken to pieces.

* *A Practical Treatise on Coal-mining*, 1879, page 148.

Mr. J. J. Couch, of Philadelphia, invented, in 1849, a percussion-drill embodying some of these features. Later in the same year Mr. Joseph W. Fowle, of Boston, invented a drill, in which the drilling-tool was attached directly to the machine, or was a continuation of the piston-rod. Subsequently, Mr. Charles Burleigh constructed a drill embodying important improvements on the Fowle drill. Since then, Messrs. Ingersoll, Wood, Githens, and Sergeant have brought the rock-drill more nearly to the requirements stated by Mr. G. G. André.

All the early drills were what are now known as "tappet drills," that is, the movement of the valve was effected by tappets projecting into the cylinder, and struck or moved by the piston. This was the principle of the valve movement of the first Ingersoll rock-drill, and Mr. J. C. Githens perfected the tappet movement, as embodied in the little giant rock-drill.

The tappet construction, however, does not fulfil one of the most important conditions of a perfect rock-drill, as a part other than the piston is exposed to violent shocks. Mr. Henry C. Sergeant made the first departure from tappet-moved rock-drills in 1873, when he constructed the Ingersoll eclipse rock-drill, which, with a few alterations, is now known as the Ingersoll rock-drill. He has since designed a new valve motion and a new rotating device, embodying them in what is known as the Sergeant rock-drill. The valve-motion of the Sergeant rock-drill is similar to that of the Ingersoll, with the addition of an auxiliary valve introduced between the main valve and the piston, by means of which the valve movement is made more positive.

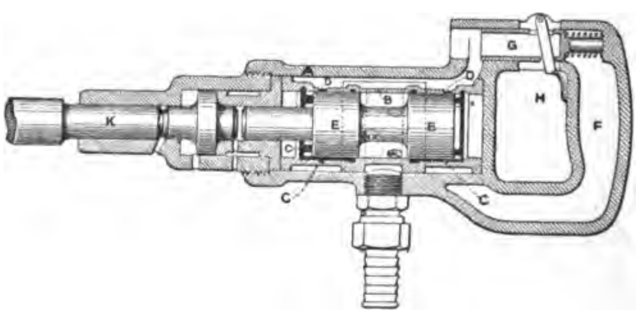


Fig. 1.

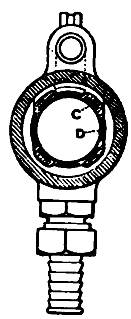


Fig. 2.

All the rock-drills referred to work on the same principle—that is, they have the drill attached to the piston, so that each upward stroke of the piston lifts the drill, and the downward stroke brings the cutting edge of the drill into violent contact with the rock to be bored. This action entails great shock and vibration on the framing and working parts of the tool, necessitating great strength of construction and consequent heavy weight.

The diamond-drill works on a different principle: the drill is revolved, a steady pressure is brought to bear upon it, and thus by the abrasion of the diamond-surfaces upon the rock, a hole is rapidly bored.

The Ross rock-drill combines the two principles—for while the piston reciprocates with a short stroke and at a high speed, the drill is always kept to its work at a uniform and carefully regulated pressure.

Figs. 1 and 2 are sectional drawings of a hand-tool; and Fig. 3 is an elevation of tripod-drill. The casing A is bored and fitted with a phosphor-bronze liner B, forming the cylinder, in which the piston works. On the outside of the bronze liner rings are cast, so as to leave annular spaces between them and the outer casing. These spaces are divided into inlet and exhaust passages for the working fluid, by suitable projections cast on the outside of the liner, and turned to fit the casing. Communication between these passages and the interior of the liner is effected by several admission-ports C, and exhaust-ports D, formed in the liner, and so placed that the piston, in its reciprocating movement, operates as a self-acting valve, automatically admitting and

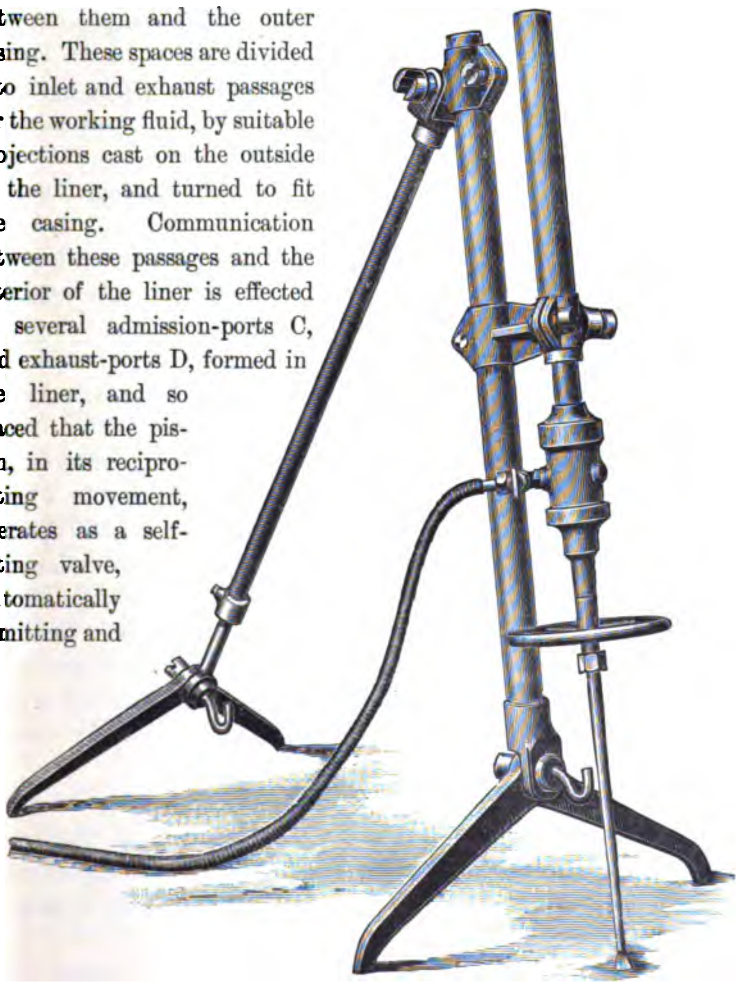


Fig. 3.

exhausting the working fluid. The piston E is a solid forging, turned and ground into the cylinder so as to work freely. It is 5 inches in length, 2½ inches in diameter, and is slightly reduced at the centre where the actuating fluid is introduced into the cylinder. The piston weighs 4½ lbs., and is the only working part in the tool.

The principle upon which the tool works is simple. The piston is reduced in diameter at the centre, leaving a collar on each end. The inside edges of these collars form the cut-off edges, while the outside edges govern the exhaust-ports.

As soon as the compressed air is turned on, the piston reciprocates with great velocity, and is cushioned at the back end of the cylinder.

The piston at each stroke strikes a centrepiece fitted into the nose of the tool, and through this the blows are conveyed to the end of the steel-drill. The collar on the centrepiece bears on a phosphor-bronze thimble, and takes up the pressure given by the automatic feed. The collar also acts as a gauge, and keeps the centrepiece at a fixed distance from the striking-end of the piston.

There is a ram attached to the back end of the cylinder, fitted with a piston working in the automatic feed-cylinder. This cylinder is connected to the framing by 2 clamps, which are bored to fit the standard and the feed cylinder, and this forms a perfect universal joint. The clamp has an open jaw, fitted with a bolt and nut by means of which the feed-cylinder may be fixed in any position.

As soon as the thumb-cock is turned on, the piston immediately gets into rapid motion, and simultaneously the air finds its way by a small channel to the outer end of the plunger, thereby pressing the drill up to its work with a steady and unvarying pressure. All that the attendant has to do is to turn the hand-wheel steadily and somewhat quickly. When the drill has penetrated to a depth of 18 inches, the plunger in the feed-cylinder having travelled out that distance, the attendant slackens the clamp a little, pushes forward the feed-cylinder till its outer end is near the clamp, fixes it by a turn of the nut, and the drill is ready for another length of 18 inches of travel.

It will be seen that holes 3 feet in depth can be bored by this rock-drill with one length of drill, and without shifting the framing in any way. The drill is clamped to the combined tripod and stretcher-bar by a single bolt. One turn of this bolt enables the workman to raise or lower the rock-drill, or to swivel it in any direction.

The top screw and nut enable the frame to be used as a stretcher-bar where the roof of a tunnel or the side walls afford support. In such cases the back stay can, of course, be disconnected and laid aside.

The advantages claimed for the Ross rock-drill are : a combination of efficiency, with lightness and strength of construction. The total weight of this rock-drill mounted on the compound tripod and stretcher-bar is 190 lbs. Great weight in the different parts is unnecessary, from the fact that the work done does not depend upon heavy blows being struck, as in the case of the ordinary rock-drill, but upon a multiplicity of light blows being given by a light piston travelling with great velocity. The piston being the only moving part in the tool, liability to fracture and derangement is reduced to a minimum.

In rock-drills made on the ordinary principle, the piston and piston-rod are actuated in their reciprocating motion by a separate valve, which very much increases the wear-and-tear of the tool. The different parts of the Ross rock-drill are of light weight, and are easily put together; it is exceedingly portable, and the heavy weights attached to the tripod, necessary in other types of rock-drills, are entirely dispensed with.

The Ross rock-drill has been thoroughly tested on a variety of rocks. With an air-pressure of 60 lbs. per square inch, the $2\frac{1}{4}$ inches rock-drill will bore holes, $1\frac{1}{4}$ inches in diameter, in the hardest whinstone, at the rate of about 4 inches per minute ; and in ordinary sandstone at the rate of 15 to 20 inches per minute.

Mr. Ross, in reply to questions, said that the drill was always pressed against the rock by the automatic feed. The drill readily cleared itself, and was not liable to heat. It had been tried in every kind of rock, with thoroughly satisfactory results. Sandstone could be drilled at the rate of 20 inches per minute, and the hardest whinstone at the rate of 5 inches per minute.

Mr. W. Archibald (Cambuslang) said that the mechanism seemed similar to that of the Harrison coal-cutting machine, which proved a regular nuisance.

Mr. Howie (Larkhall) said that with drills on the Harrison principle the great difficulty and drawback was the back stroke, but this drill was entirely different. There was no doubt that the want of an automatic feed was a drawback.

Mr. Ross said that the drill described in his paper was entirely distinct from the Harrison machine.

The discussion was then adjourned.

HISTORICAL NOTES ON EARLY PLANS FOR COAL-WASHING.

By F. J. Rowan.

In the course of a recent investigation into some rival systems of coal-washing, the writer became acquainted with some descriptions of such plant, the completeness of which was surprising on account of their comparatively early date. They show that, many years before coal-masters in Great Britain could be persuaded to adopt even part of the apparatus proposed, some engineers had a very clear conception of the problem of coal-cleaning and classifying, and a comprehensive grasp of the requirements of the process.

This is especially seen in what is probably the first British patent specification in connexion with this subject that ever was published. This patent was secured by the late Mr. E. A. Cowper in 1849, as a communication from a foreign correspondent. The series of operations provided for under this invention was as follows:—The coal from the hutches was elevated by a chain of buckets and thrown on to a classifying-screen or sieve. The lumps passing from it went either to a picking-table or, if impure, to rollers to be crushed and returned to the classifying-screen. The screen being composed of several plates having differently sized perforations arranged in stages, the small coal was separated into different sizes which were then passed on to the water-sieves of the jigging-machines. These washing-machines had all the essential features of those now in use, including an adjustable fence-plate or sluice for the separate escape of the pyrites or schist. The washed coal on escaping from the washer fell on to a draining-screen, from which it was passed on to receptacles provided for it, and the water might be used over again. As described by the inventor, "the process of purification consists of two distinct operations following each other uninterruptedly, viz.:—(*a*) classification in order of size, and (*b*) water-sifting for separation in order of density. The classification of coal in order of size," he says, "has been heretofore performed as a commercial operation to obtain various qualities of coal for sale, but the classification by a continuous process and for the purpose of being applied to the subsequent operation of purification has never hitherto been employed and such application of it is quite new.

The classification may be effected in a different manner and with various modifications of apparatus differing from that above described while the principle remains the same. Thus the classification may be performed by means of a cylindrical or conical sieve, similar to, but larger than a flour-dressing machine; or by means of horizontal plates, with the assistance of centrifugal force; or sieves of various forms may be employed, fixed on the same plane and formed of perforated plates or metallic cloth or net with various sized apertures, or as already mentioned, the plates may be placed one above another in the same frame; but in whatever manner the classification is effected, if it is employed in combination with the water-sifting process for the purpose of purifying the coal, it will come within the principle of this invention. With regard to the second part of this process, that is to say, the water-sifting for the separation of the substances in order of density, the system combines several new facts, especially the separation of the different substances by a continuous process, and the continuous employment of the same water for that purpose. It will," he adds, "be easily understood that the above-described process and machinery are not restricted to the purification of coal only, but may be used for separating other solid substances of different specific gravities, provided that their specific gravities exceed that of water."

It must be admitted that this specification presented a very complete scheme to the coal-masters of this country, and it was unfortunate for the inventor that he appeared so much in advance of the times. Mr. Cowper followed up this patent by describing, in 1851, some improvements in the apparatus or methods of working. These had in view especially the dealing with intergrown or stratified coal, and with the handling and collecting of the dust from the washing-machines, etc. The dust was to be flushed with water from the draining screens, so as to be conveyed into a sludge-collector.

It is supposed that these communications emanated from M. Bérard, whose washing-machine or jigger was shown at the Great Exhibition held in London in 1851.

The concentric cylindrical screen or riddle was patented in 1854 for sifting and washing gravel or other similar substances, but such apparatus for screening coal was first proposed in Great Britain by Mr. Dutton in 1867, who describes very fully this form of apparatus, consisting of "two or more concentric cylinders made of bars, wire-gauze, or perforated metal, and revolving within one another." The mesh or pitch of the screen-cylinders was to be largest in the inner and smallest in the outer cylinder, so that the coal of largest size should be screened in the inner

cylinder, and coal of the smallest size in the outer cylinder. The cylinders might revolve at the same or different speeds and in any direction. This is also a pioneer patent, because simple cylindrical screens were introduced into France only in 1863, and concentric cylindrical screens not until 1877.

Although several inventors are found entering the field of coal-washing plant design between 1865 and 1871, it was not until 1872, that anything very original was proposed. But in that year Mr. Upfield Green patented as a communication from a German source the use of what he calls "equivalents." "When using the apparatus," he says, "the smaller divisions are partly filled with 'equivalents,' that is to say, with grains of mineral or material having equal velocity of fall in water, and of a certain determinate size. Observing that, proceeding from the first sieve, the proportionate size or density of the equivalents contained in every successive sieve must be increased. To balance the contents and to secure unvarying regularity, the discharge-openings are in direct communication with the upper surface only of the beds, and therefore, unless at this stage additional stuff be supplied to the jigger, none can pass out. Thus the beds are rendered permanently the same whether they are augmented or not by further equivalents."

It is evident that this patent describes the fundamental principles of what have since then become known as felspar-machines.

With Mr. Sheppard, in 1873 and 1876, began the modern stage of development of coal-washing plant, followed by Mr. Coppée in 1882, Mr. R. Robinson in 1884, Mr. Hall and others following later with plans with which all are familiar; but, however excellent are the improvements in details which these have introduced, none have surpassed in comprehensiveness the early pioneers in this branch of engineering design.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

SPECIAL GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, SEPTEMBER 24TH, 1894.

MR. R. H. COLE, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The officers for the ensuing year were nominated.

AMBULANCE CLASSES.

Mr. W. N. ATKINSON (H. M. Inspector of Mines) said that in July last the Secretary of State for the Home Department addressed a letter to the Inspectors of Mines requesting them to take every opportunity which might present itself of promoting the formation of ambulance classes amongst all persons employed in mines. In pursuance of this instruction he had sent a circular to the colliery owners in this district asking them to encourage the establishment of ambulance classes, where their officials and workmen might acquire instruction in first aid to the injured. He did not think it was necessary for him to enlarge on the benefits to be derived from such knowledge by persons engaged in a dangerous occupation such as mining; and further, there was every wish on the part of the colliery owners and managers to take advantage of the facilities offered by the St. John's Ambulance Association for the instruction of their officials and workmen in the principles of first aid to the injured. In the autumn of 1890, this institute promoted the formation of a number of ambulance classes for miners in North Staffordshire. These classes were successfully conducted and attended by a considerable number of miners and mine officials. The classes were taught by various doctors in the district, who, with a generosity which marks the profession, gave their services gratuitously. With a view to establish a scheme for the annual formation of ambulance classes for miners in North Staffordshire, he

again brought the subject before the Council of the Institute, and it had been decided that the Council would make the necessary arrangements in conjunction with Mr. S. M. Copeland, the Secretary of the St. John's Ambulance Association for the Potteries centre. He was sure that the members of the Institute would, so far as they were able, encourage their officials and workmen to attend the ambulance classes; and he might add that candidates for managers' and under-managers' certificates of competency would find a knowledge of ambulance work especially useful, because the Board for Examination in this district had added the subject to those in which candidates might be examined.

Mr. S. M. Copeland, the Secretary of the Potteries centre of the St. John's Ambulance Association, suggested that the plan adopted in 1890 should be followed as it worked well.

The President said that the desire was that each colliery should have a number of workmen skilled in ambulance work to render first aid in case of an accident.

Mr. W. N. Atkinson said that the great object was to provide some means of having annual classes; and that the classes should be carried on from year to year. He moved that the Council of the Institute should be a Committee to make the necessary arrangements.

Mr. J. R. Haines seconded the motion, which was passed unanimously.

Mr. B. Woodworth read the following "Notes on the Practicability of Working the Thin Coals of North Staffordshire," etc.:—

NOTES ON THE PRACTICABILITY OF WORKING THE THIN COALS OF NORTH STAFFORDSHIRE BY THE ADOPTION OF MECHANICAL APPLIANCES.

BY B. WOODWORTH.

There can be no dispute as to the loss of national wealth by reason of thin seams of minerals not being worked, nor can there be any doubt that posterity will suffer from the effects of either wasteful working or neglect of valuable mines which, owing to their thinness, are not capable of being worked remuneratively by ordinary means. The problem, therefore, to be considered is, can we do anything successfully by adopting available mechanical assistance? To solve such a problem the trial must be made in a comprehensive manner, so as to give a reasonable chance of profitable working; consequently a very considerable outlay is required, rendering such trials impracticable for all but the most wealthy proprietors to attempt single-handed. It is seldom that a combination of the needful resources and skilled knowledge is found, along with sufficient enthusiasm to undertake and carry out such an attempt.

Is there any chance of dealing with such a matter by a combination or company, selecting a representative thin coal-mine or mines, and working it or them especially by mechanical means, independently of the other parts of the works carried on in the ordinary manner? This project would be worthy of the support of the mining proprietors of this district, as they would acquire a maximum of knowledge and experience for future use at a minimum of cost: the particulars of working and the results would be available for all the adventurers. This question is a matter of equal if not of greater importance to royalty owners, who ought to contribute in fair proportions, as they would eventually benefit largely by the successful solution of such a problem.

Many of the members could fix upon suitable places wherein to make such experiments, with reasonable prospects of successful results being obtained. The test should be made on a scale of considerable magnitude, and whether it should be carried on independently of the department dealing with the produce, or whether the produce should be sold to the proprietors of the colliery selected for the experiments, would be a matter of arrangement.

To carry out such a series of experiments, after arranging for the provision of the necessary capital, the writer suggests that the management should be placed in the hands of a president (with one mining and one mechanical engineer), who should be responsible for all the details of working, and selection of the machinery and apparatus required.

The first and most important matter to be decided upon would be the selection of the motor power, the choice, in the writer's opinion, being limited to compressed air or electricity; in either case a well-designed and economically-working plant is absolutely necessary, which should be purchased.

As regards machinery for heading, drilling, coal-cutting, and haulage arrangements, possibly the rival makers of such machines would be prepared to supply them on favourable terms for preliminary trials of an exhaustive nature, after which all needful purchases could be made of those machines found suitable for the successful working of the mine.

In selecting the colliery in which the experiments should be made it would be necessary to have full information as to the extent of the seam or seams to be worked, the position of the faults, and the dip of the mine (the latter, in the writer's opinion, should not exceed 14 to 16 inches per yard). If a suitable division could be arranged without injury to the general scheme, the writer suggests that a portion of the mine should be wrought by the ordinary system, so that accurate comparisons of the cost of both systems might be obtained.

Mr. Bailes said that the chief difficulty in working thin seams in the North Staffordshire district was their steep inclination.

Mr. Woodworth said that the object of his notes was not to recommend coal-cutting machines, but to test the possibility of working seams with machines that were unworkable without them.

Mr. E. B. Wain thought that the principal difficulty would be not so much with the mechanical means as in getting the men to work in very thin seams. Seams a little over 2 feet in thickness in North Staffordshire were worked successfully; but there would be difficulty in moving the machine, and also the difficulty of getting men to work in thinner seams.

Mr. Hobbs inquired whether Mr. Woodworth intended to work the coal-cutting machines up bank or down bank?

Mr. Woodworth replied that he thought that the machines would be wrought in both directions according to circumstances.

Mr. BAILES asked whether a thin coal could be worked in competition against the produce of a thick seam?

The PRESIDENT asked if any member could mention the thinnest coal-seam without ironstone worked in North Staffordshire?

Mr. A. HASSAM answered that 25 inches of coal was being worked at the Sneyd colliery.

Mr. H. M. LYNAM remarked that the question was whether there were any considerable number of seams of that thinness which were not being worked. Mr. Woodworth led them to infer that there was a quantity of coal not worked because the seams were too thin, and he wanted to know whether it was possible to work those seams by mechanical means with profitable results.

Mr. WAIN said that if mechanical means were successful in thin seams the same method would be carried into thick seams, and the thin ones would be again driven out of the market.

Mr. ATKINSON observed that when they considered the slow progress made with mechanical coal-cutters where the circumstances were most favourable, it was hardly likely that they would come into use in North Staffordshire, where most of the conditions were extremely unfavourable; viz., the steep inclination of the seams, the bad roofs, and the number of thick coal-seams where the advantages of a coal-cutting machine would be reduced to a minimum.

The discussion was then adjourned.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN THE MASON COLLEGE, BIRMINGHAM, OCTOBER 8TH, 1894.

MR. JOHN FIELD IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

The following gentlemen were elected:—

MEMBER—
Mr. ALBERT ERNEST THOMAS, Mining Engineer, Camborne.

STUDENT—
Mr. FRANCIS GERTIN PEAKE, Walsall.

The annual report of the Council, together with the Auditors' report, and accounts, were read as follows:—

REPORT OF THE COUNCIL.

The Council have pleasure in congratulating the members upon the success of the past year.

Nineteen new members have joined the Institute, ten have resigned or have been removed from the register, so that the total number is 137, as against 128 in the previous year.

The total receipts have been £198 14s. 7d., and the expenditure £155 10s. 10d., so that the bank balance has been increased by £43 3s. 9d., and now stands at £317 19s. 4d.

Six general meetings, seven Council meetings, and two meetings of the Technical Education Committee have been held during the year.

The following papers have been read:—

"A Contribution to the History of Fire-damp." By Mr. H. G. Graves.

"A New Method of Tamping and Ramming Bore-holes." By Mr. Hy. Johnson.

"Ancient Mining at the Coppice Sedgley." By Mr. Isaac Meachem, Jun.

"The Structure of the Forest of Wyre Coal-field." By Mr. Daniel Jones.

"The Jeffrey Electric Coal-cutting Machine." By Mr. R. S. Williamson.

The meetings at which Mr. Daniel Jones' paper was read and discussed were held under an arrangement with the Dudley Geological Society, whereby the members of the Society attended, and the proceedings were a great success.

The Technical Education Committee of this Institute has continued, under the able chairmanship of Mr. Arthur Sopwith, to arrange the lectures, classes, and examinations for the Staffordshire County Council's Mining Instruction Scheme, the result has been satisfactory, and the classes are fairly attended and much appreciated by the miners.

The Federated Institution of Mining Engineers, with which this Institute is connected, has continued to prosper, and now has on its register upwards of 2,200 members. The President for the past year was Mr. Arthur Sopwith of this Institute. Its general meetings have been held during the year in Scotland, Yorkshire, and London, and many important papers have been read and discussed, as will be seen from the volumes of valuable *Transactions*.

The original estimate of contribution of 15s. per member of the Federated Institution of Mining Engineers has been found inadequate to meet the expenses, and additional calls have been made, which will necessitate consideration on the part of the lesser Institutes, who, to some extent, re-organized their finances and subscriptions to meet only the first estimate.

The next meeting will be held in the Birmingham district on Tuesday and Wednesday, February 12th and 13th, 1895, under the auspices of this Institute, and everything must be done to make the visit more satisfactory even than the last.

The best thanks of this Institute are due, and are hereby tendered, to the authorities of Mason College for providing rooms for the meetings.

The Council again wish to impress upon the members the necessity of making the Institute more useful by inducing under-managers to become associates, and pupils to become students, at the reduced fees, so that they may enjoy the privileges and educational advantages of attending the meetings and receiving the *Transactions* of The Federated Institution of Mining Engineers.

Dr. THE TREASURER IN ACCOUNT WITH THE SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS, FOR THE YEAR ENDING JULY 31ST, 1894. **Cr.**

	£	s.	d.		£	s.	d.
To Bank Balance ...	274	15	7	By Subscription to The Federated Institution of Mining Engineers from August 1st, 1893, to July 31st, 1894	71	5	0
,, Subscriptions Received	193	18	6	,, Secretary's and Reporter's Fees for same period ...	50	0	0
,, Bank Interest ...	4	16	1	,, Printing, Stationery, etc.	12	3	7
				,, Stamps, Circulars, Telegrams, Arrear Circulars, Porterage, etc.	4	17	9
				,, Secretary's Expenses attending Meetings of The Federated Institution of Mining Engineers	5	5	0
				,, Donation to Mason College ...	10	10	0
				,, Fee to Porter at Mason College	1	0	0
				,, Bank Charges ...	0	9	6
				,, Balance	317	19	4
	£473	10	2		£473	10	2

BALANCE SHEET, 1893-4.

Liabilities.	£	s.	d.	**Assets.**	£	s.	d.
To Federated Institution of Mining Engineers for extra calls to make up their deficiency and for expenses in connexion with *Transactions*	25	4	10	By Cash at Bankers	317	19	4
,, Balance	391	1	9	,, Subscriptions due	98	7	3
	£416	6	7		£416	6	7

Examined and found correct,

DANIEL ROGERS.

October 4th, 1894. WILLIAM H. WHITEHOUSE.

This is exclusive of considerably more than £100 worth of property, for which no credit is taken.

Mr. Arthur Sopwith moved the adoption of the reports of the Council and of the Auditors, and of the accounts for the past year.

Mr. W. F. Clark seconded the resolution, which was unanimously adopted.

ELECTION OF OFFICERS FOR 1894-95.

The Scrutineers reported that the following gentlemen had been duly elected:—

President.—Mr. H. C. Peake.

Vice-President.—Mr. J. H. Cooksey.

New Members of Council.

Mr. J. Broughall.	Mr. T. J. Davies.
Mr. F. G. Meachem.	Mr. R. Thomas.

Mr. H. C. Peake then took the chair and delivered the following Presidential address:—

PRESIDENTIAL ADDRESS.

BY H. C. PEAKE.

I must first thank the members for the honour which they have conferred on me by electing me President, and I will endeavour with your assistance to do my duty and uphold the dignity of the Institute during my term of office. The ground for an address has been so often gone over before that there is little left which is either new or interesting. I will not detain you long, but ask your patience for a few thoughts which have occurred to me.

One of the questions which has lately engaged our attention has been the agitation on behalf of, among other workingmen, those employed underground in the collieries of this country for shorter hours of labour. Should the proposed so-called "8 hours day" for miners come into force, greater pressure and responsibility will be thrown upon mining engineers, and it becomes a matter for consideration as to the best means of meeting the difficulties which will arise.

I do not think that the owners of collieries need fear anything—in fact, for a time at any rate, the restriction of output, which will probably follow, should have the effect of giving increased profits.

I am not an advocate of long hours of labour, or of cheap labour, but I cannot see how shortening the present working hours—in this district at present exactly eight per day at the outside—will tend to help the workmen employed underground. The agitation which seems to have been carried on without any calculation as to the result is, to my mind, analogous to children crying for sweets, and not thinking of the pain which usually follows.

In this case, I have not noticed that anyone has considered the effect of the shortening of the drawing hours at a colliery—that is, with the same appliances. No one can deny that it must lead to a diminished output.

It is equally clear that to make the same return on capital, and to allow for the increased amount per ton for standing charges, a larger price must be obtained for the coal sold, and if this cannot be obtained capital will not be sunk in a business, which at the best is risky, and from which, when once invested, there is little chance of withdrawing the invested capital.

One of the most amusing arguments is—that it will tend to equalize the working hours, more equally between summer and winter; but it is absurd to think, because there is a greater scarcity of coal in the winter, that more will be consumed during the summer.

In order to produce the same quantity of coal, the workmen would be actually longer underground with the shorter than with the longer hours—a larger proportion of the time being taken up in going to and returning from their working-places, and naturally the risk of accident would thereby be increased. This argument, which was originally one of the chief ones in favour of the shortened hours, is not, however, now being relied on to assist the agitation, since it has been found that as many or even more accidents take place in the earlier hours of work as during the later.

I am not going into the result of the shortened hours so much as affecting trade, which Mr. E. M. Bainbridge has been writing about in one of the magazines, but merely as to how—should they take place—the relationships between capital and wages can be best maintained without unduly depressing the latter.

Owing to the higher prices at present ruling, and perhaps to a similar extent to the cessations in work which have taken place, and which are a shortening of the hours on a more gigantic scale than was perhaps intended, trade is depressed to a great extent, I believe, as far as domestic consumption is concerned, by economies which have been effected by consumers in various ways. For instance, by using gas for cooking during the summer months, when fires for heating are not required—although coal is necessary for the production of that gas—a much smaller quantity suffices. Petroleum stoves are also largely coming into use for cooking, and are, if anything, more economical than gas, the advantage of both being that they can be extinguished when not required. The consumption of mineral oil in place of coal is not confined, however, to domestic purposes. It is being used by manufacturers, even in this district, for heating iron and for steam-raising in stationary and locomotive boilers.

I have no hesitation in saying that, at first, the burthen of the increased cost will have to be chiefly borne by workmen other than miners; then, for a short time, it will have to be borne by the coalowners; and finally it must fall on the colliers themselves.

The shortening of hours will be carried out eventually, with the least loss to the workmen, by increasing the coal-output for the same capital outlay, so as to spread the interest on capital and the standing charges over a larger tonnage. This can be effected in several ways, such as working two shifts, improvements in mechanical arrangements, &c.

From the point of view of the mining engineer, the question will have to be considered as to where improvements can be effected, although more scientific ways in working the coal must not be neglected. Amongst the possible improvements are :—

(1.) Mechanical holing and cutting of the coal, and these are now quickly coming to the front.

(2.) The tubs into which the coal is loaded for conveyance to the pit-bottom should be made as handy and easily loaded as possible, and they should be adapted to the seam in which they are used; as a rule, the height should be kept as low as possible to avoid breakage in loading, and to enable the workmen to load the coal with the least exertion.

(3.) Conveyance of the coal from the working-place to the pit-bottom.

(4.) Quicker winding in the shaft.

(5.) Preparation of the coal on the surface, and putting it into the best marketable condition, with as little cost and breakage as possible.

In scientific mining, I am inclined to think that the propping of the roof so as to make the weight assist in bringing down the coal in a more marketable condition has not been carried into effect as much as it might have been, and although much has been written about timbering with regard to safety, there seems room for further papers and discussion on the subject.

The chief event of the coming year is that in February next a meeting of The Federated Institution of Mining Engineers will be held in this district, when I trust the members will be able to offer a hearty welcome to our friends from other parts, although we may not have so many new appliances to show as in other districts; perhaps if there is no other novelty, they may see something which it is desirable to avoid.

An unanimous vote of thanks was then accorded to the President for his address.

The PRESIDENT moved a vote of thanks to Mr. G. H. Claughton for his services as President during the past year.

Mr. JOHN FIELD seconded the motion, which was unanimously adopted.

Mr. DUIGNAN proposed a vote of thanks to the Council and the officers for their services during the past year.

Mr. I. MEACHEM, Jun., seconded the resolution, which was approved.

Mr. W. J. HAYWARD (treasurer), in returning thanks, referred to the visit in February next of The Federated Institution of Mining Engineers, and expressed a hope that the members would assist in promoting the success of that meeting.

The meeting then closed.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
NOVEMBER 24TH, 1894.

MR. THOMAS DOUGLAS, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the previous General Meeting and reported the proceedings of the Council of that day.

The following gentlemen were elected, having been previously nominated :—

HONORARY MEMBER—

Mr. WILLIAM GARNETT, M.A., D.C.L., 13, Spring Gardens, London, S.W.

MEMBERS—

Mr. B. ANGWIN, Mining Engineer, P.O. Box 231, Johannesburg, Transvaal.

Mr. GEORGE BELLINGHAM, Licensed Land and Mining Surveyor, Coolgardie, Western Australia.

Mr. ALFRED HAMMOND BROMLY, Mining and Mechanical Engineer, Llannwchllyn, near Bala, North Wales.

Mr. RONALD C. CAMPBELL-JOHNSTON, Metallurgist, Assayer, and Mining Engineer, P.O. Box 40, Vancouver, British Columbia.

Mr. HENRY REYNOLDS CHAPMAN, Mechanical Engineer, Victoria Works, Gateshead-upon-Tyne.

Mr. ROBERT EDDEN COMMANS, Mining Engineer, 6, Queen Street Place, London, E.C.

Mr. RICHARD STAFFORD COUSINS, Civil Engineer, Coach Road House, Whitehaven.

Mr. ROBERT FOWLER, Colliery Manager, Washington Colliery, Washington Station, R.S.O.

Mr. HENRY RICHARD HANCOCK, Superintendent, Wallaroo and Moonta Mines, Moonta Mines, South Australia.

Mr. REIJI KANDA, Mining Engineer, c/o Mr. Takahira Kanda, 9, Awajicho-Nechome, Kanda, Tokio, Japan.

Mr. HEINRICH WILHELM FERDINAND KAYSER, Mining Manager, The Mount Bischoff Tin Mining Co., Waratah, Tasmania.

Mr. WILLIAM LECK, H.M. Inspector of Mines, Cleator Moor, Cumberland.

Mr. DUNCAN MCGEACHIE, Manager, Waratah Colliery, Charlestown, near Newcastle, New South Wales.

Mr. D. H. F. MATTHEWS, H.M. Inspector of Mines, Newton-le-Willows.

Mr. James Jones Meldrum, Manufacturing Engineer, Atlantic Works, City Road, Manchester.

Mr. Septimus Oliver, Mining Engineer, Tyne House, Tynemouth.

Mr. Frederick Danvers Power, Mining Engineer and Metallurgist, c/o Messrs. Henderson & Macfarlane, 2, Bridge Street, Sydney, New South Wales.

Mr. William Edward Sam, Jun., Mining Engineer, c/o Messrs. F. & A. Swanzy, Cape Coast Castle, Gold Coast.

Mr. Harry Sladden, Mining Engineer, Chorlton Chambers, P.O. Box 1666, Johannesburg, Transvaal.

Mr. George Paton Walsh, Engineer, 138, Reguliersgracht, Amsterdam, Holland.

Mr. Horace V. Winchell, Geologist and Mining Expert, 316, Tenth Avenue, S.E., Minneapolis, Minn., U.S.A.

Associate Members—

Mr. Alfred Molyneux Palmer, Coal Owner, 14, Windsor Terrace, Newcastle-upon-Tyne.

Mr. Sydney C. Rudman, Land Agent and Engineering Surveyor, Estate Office, Windlestone, Ferryhill.

Mr. Robert Sheard, Engineer and Boiler Builder, Caldervale Boiler Works, Wakefield.

Mr. G. Young Wall, Manorial Surveyor and Local Deputy Steward to the Ecclesiastical Commissioners for England, Halmote Court Office, New Exchequer Buildings, Durham.

Associates—

Mr. Arthur Morton Hedley, Assistant Overman, Barrow Collieries, Barnsley.

Mr. James Stokoe, Overman, Murton Colliery, *via* Sunderland.

Students—

Mr. John Henry Bacon Forster, Mining Student, Hetton Colliery, Hetton-le-Hole, R.S.O.

Mr. Nathaniel Maurice Griffith, Mining Student, c/o Broughton & Plas Power Coal Co., Limited., Wrexham.

Mr. Tom Alfred Lishman, Mining Student, The Tower, Durham.

Mr. Albert Littlejohn, Mining Student, Ashington Colliery Offices, Morpeth.

Mr. Philip Neasham, Mining Apprentice, Colliery Office, Medomsley, Co. Durham.

Mr. Norman Nisbet, Mining Apprentice, Tantobie, Co. Durham.

The following gentlemen were nominated for election :—

Members—

Mr. G. A. Denny, Mining Engineer, Farm Tusschenby, Denny Dalton Gold Fields, Vryheid District, Transvaal.

Mr. Thomas Gilbert Dobb, Mining Engineer, Derby Terrace, Hindley, near Wigan, Lancashire.

Mr. Edgar Tom Gardiner, Mechanical Engineer, 8, South View Terrace, Bishop Auckland.

Prof. Edward Hull, Consulting Geologist, 20, Arundel Gardens, London, W.; and 4, Fenchurch Avenue, London, E.C.

Mr. John Murray, General Manager, Raneegunge Coal Association, Limited, Giridih, India.

Mr. Alexander Ross, Manager, Wallsend Colliery, Newcastle, New South Wales.

Mr. Frederick Augustus Thompson, Mining Engineer, Broad Street House, London, E.C.

Associate Members—

Mr. James Dodds, Pearson and Knowles' Coal and Iron Company, Limited, Dallam and Bewsey Forges, Warrington.

Mr. F. Gillman, Gartenstrasse 1, Freiburg, Baden, Germany.

Mr. George Ernest Gregson, Land Agent, and Land and Mine Surveyor, 11, Chapel Street, Preston.

Mr. Charles Albert Smith, Ropemakers' Representative, 20, Alexandra Place, Newcastle-upon-Tyne.

Associates—

Mr. George Eltringham, Master Shifter, Shiremoor Colliery, Newcastle-upon-Tyne.

Mr. John Harrison, Under-manager, Ashington Colliery, Northumberland.

Mr. Robert Linday, Colliery Surveyor, Bishop Auckland.

Mr. John Henry Miller, Colliery Surveyor, South Hetton, Sunderland.

Students—

Mr. Walter Newton Drew, Articled Pupil, Thorncliffe Collieries, near Sheffield.

Mr. William Denham Harbit, Mining Student, 32, High Street, Wallsend.

Mr. Joseph Henry Sherwen, Mining Student, Marina Terrace, Hensingham, Whitehaven.

DISCUSSION ON THE "REPORT OF THE PROCEEDINGS OF THE FLAMELESS EXPLOSIVES COMMITTEE. PART I.—AIR AND COMBUSTIBLE GASES."

Mr. A. C. Kayll read the "Report of the Proceedings of the Flameless Explosives Committee. Part I.—Air and Combustible Gases."

The President hoped that the enquiry would bring about some important results, and that they would be assured as to whether they could with safety use high explosives in coal-mining operations.

Mr. A. L. Steavenson said that the subject was a very difficult one to deal with, and he had no desire to find fault with the valuable report of the Committee. They were told in the report, the claim had been made for flameless explosives "that when exploded the temperature of the gaseous products was so low that they were incapable of igniting fire-damp

or coal-dust, and that such explosives were safe for general use in mines."* Whether this was claimed for high explosives or not, he did not think it was correct; his impression was that the temperatures produced by high explosives were extremely high and intense, and that blasting-powder produced a much lower temperature of a more protracted nature in its explosion. In that respect it was more dangerous, because pellets of the powder were thrown out by a blown-out shot and passed down the gallery in a state of ignition. He had on previous occasions referred to a case coming within his own knowledge in which blasting-powder had been blown a distance of 40 or 50 feet, burning a workman who was sitting without his shirt. The markings of the pellets on a tub were easily observed. It was further stated that the enquiry was "instituted with the object of clearing away the doubts and uncertainties connected with the employment of safety explosives in mines."† He would like to have seen blasting-powder tested in the same way; probably the results would have been disastrous to the reputation of powder, but it would have been interesting to have had the results recorded. They were also told of the means adopted by Messrs. Bedson and Shaw for testing the strength of the different explosives, and a little drawing was given on the plan (Fig. 10, Plate I.), but he thought that this did not give quite sufficient information as to what the process was.‡ He presumed that after the explosion of a charge in the leaden cube, the volume or space was measured by means of water, and thereby one arrived at a comparison of the relative strengths of the explosives.§ The general tenor of the report seemed to point very distinctly to the safety of carbonite, and it seemed pretty clear that in all the experiments carbonite had done excellently. He suggested that there should be a few more tests made with carbonite, for if it were true that carbonite was safer than the other explosives it was desirable that this should be made clearly known. It was stated that experiments were not made with stemmed shots fired into air only for the purpose of observing the presence of flame,‖ but if the Committee had time he thought it was desirable that they should make further experiments on this point alone. It might not alter the results obtained in the recorded experiments, but it would form concurrent testimony of their value. It was stated that all high explosives were less likely to ignite gaseous mixtures than blasting powder, but this was without proof, and he suggested that further experiments should be made with powder to decide that question.

* *Report*, page 3. † *Ibid.*, page 5. ‡ *Ibid.*, page 16. § *Ibid.*, Table I., page 17. ‖ *Ibid.*, page 24.

Mr. HENRY HALL (H.M. Inspector of Mines) said that the Institute was to be congratulated on having undertaken these valuable experiments, and on having brought them so far to a successful issue; and more especially were the gentlemen to be congratulated who had conducted the experiments and devised the necessary appliances for carrying them out so successfully. It appeared to him that all the high explosives which had been tested, either stemmed or unstemmed, were capable of igniting explosive mixtures of coal-gas and air, but in the case of explosive mixtures of pit-gas and air—and they had to draw a distinction between pit-gas and coal-gas—when unstemmed, some of them ignited the gaseous mixtures and some did not; when fired in the usual way with stemming, none of the explosives ignited the mixture of pit-gas and air. They were led to suppose that this came about from the fact that there was a difference in the temperature necessary to ignite coal-gas and air and pit-gas and air, and that that difference only amounted to something like 34 degs. Fahr. It took about 1,232 degs. Fahr. to ignite pit-gas and air, and 1,198 degs. Fahr., or about 34 degs. less, to ignite coal-gas and air, so that the whole of the safety of high explosives depended apparently on this small difference of temperature.* This difference seemed a very slender thread to depend upon, and he himself thought that it might possibly disappear altogether under certain circumstances. For instance, he thought it very likely that certain kinds of pit-gas would explode at different temperatures, and that they might have a slow gas and a quick one. The gas with which these experiments were tried came, he believed, direct from blowers in the mine, but possibly it was not as quick as another gas might be, which issued freshly from the working-face of another mine. They all knew that there was a great deal of difference in the behaviour of gases underground; some, when ignited, showed a long cap, and some a short cap. He himself had ignited pit-gas with a red hot poker, but they might seek a pit through before they would find gas which they could ignite again in that manner; still, very inflammable gas did sometimes appear in pits and that which appeared from freshly-cut coal-faces might be more readily ignited than gas which had been merely pent up or derived from blowers in a coal-mine. Questions also arose which might do away to some extent with safety, such as the bulk of the flame brought in contact with the explosive mixture. In these experiments, very small charges of explosive were used; possibly if larger charges had been used—charges such as would be used underground in firing shots—some of the

* *Report*, page 36.

results might have been different, for he believed it was admitted that even flame of a fixed temperature if applied in large volume would sometimes ignite a gaseous mixture which a small volume would not ignite. He thought it most desirable that in future, experiments on this point should be taken into consideration, and that instead of dealing with an ounce of the explosive they should deal with the usual charges used underground. In addition to the danger of igniting mixtures of fire-damp and air underground with explosives, there was also the danger of igniting coal-dust; and it would almost seem from experiments which had been carried out, that coal-dust could be more readily ignited than mixtures of fire-damp and air. Possibly that arose from the fact that coal-dust was ignited by bringing it into contact with a flame which had the effect of heating it, and so distilling gas from the coal; the gas thus distilled was not fire-damp, but more nearly approached lighting-gas or coal-gas, which could be lighted by a flame of lower temperature, so that possibly dust might be ignited by an explosive which would not ignite gas and air. Recent experiments at Wigan showed that nearly all high explosives when fired in charges of one pound without any stemming, ignited coal-dust, gas being absent. Ardeer powder, carbonite, and westphalite were, however, exceptions. But although the experiments made by the Committee had shaken their confidence in the safety of high explosives, he thought there could be no question that these were very much safer than the old-fashioned explosives. He thought this safety was more especially due to two causes: first, that high explosives were not nearly so liable to produce blown-out shots, which were the real cause of the danger; and, second, that the ignition of fire-damp mixtures did not depend so much upon the temperature of the flame as upon the rapidity and the instantaneousness of the production of the flame. He agreed with Mr. A. L. Steavenson that the temperature of these safety explosives was very high; much higher than was necessary to inflame coal-gas and air or pit-gas and air. There was one point he would like the Committee to take into consideration, if possible, in future experiments—and if the future experiments became very expensive, he had no doubt the matter would be considered of such public importance that they might obtain funds from H.M. Treasury to assist in carrying them out—and that was in regard to the amount of force developed by explosive mixtures of fire-damp and air. He had always felt that mining engineers were very much in doubt upon this point, and now that they had this expensive apparatus, he thought the question might be solved. He thought the mining profession, as a rule, had no definite information upon the question as to what damage a small amount of gas might do.

Mr. M. Walton Brown said that the Committee had not been able to obtain a sufficient supply of westphalite for the purpose of the experiments. The makers had been asked to send a supply, but the request had not been acceded to.

Mr. C. C. Leach asked Mr. Hall to give a description of the cannon which had been used in the experiments in which charges of one pound of explosive were used ?

Mr. H. Hall said that the cannon had proved of sufficient strength to withstand the effects of the explosives when fired untamped. He understood that the cannon had cost about £120.

Mr. M. Walton Brown said that he had assisted Mr. W. Foggin in making a large number of experiments with charges very much lighter than those mentioned by Mr. Hall, with the result that two cannons were destroyed, and the danger of the experiments would have been greatly enhanced if the weight of the explosive had been increased. The temperature of the ignition of fire-damp was about 1,200 degs. Fahr., but it was necessary that the effects of such a temperature should be prolonged for some time in order that the mixture might be ignited. The experiments of the French Commission showed that the retardation of ignition characteristic of fire-damp mixtures, the almost instantaneous mixture of the gases resulting from the ignition of the explosive with the surrounding air, and the quick cooling consequent thereon, combine to make explosives whose temperature of detonation is less than 4,000 degs. Fahr. incapable of igniting explosive mixtures of fire-damp and air, under normal conditions of use; that is to say, in holes and properly stemmed. A further point in the use of explosives seemed to be the fact that the safety of their ignition in an explosive gaseous mixture depended upon the almost instantaneous mixture of the gases produced by the detonation of an explosive with a sufficient volume of surrounding air. It was highly probable that it might be dangerous to fire a shot in a too limited space and with a weight of explosive too great for the volume of the surrounding air as compared with the volume of the gases produced by the detonation. Perhaps Dr. Bedson would give them some information as to the temperature of ignition of pit-gas and coal-gas alone and in mixtures with air. In the "Report of the French Commission on the Use of Explosives in the Presence of Fire-damp in Mines," it was stated that "the apparent temperature of ignition of a mixture of air and gas and coal-gas containing 10 per cent. of this gas, would, therefore, be about 3,812 degs. Fahr. With mixtures of air and fire-damp,

the temperature was found to be about 3,992 degs. Fahr."* Messrs. V. Meyer and Münch state that marsh-gas ignited at 1,232 degs. Fahr., and coal-gas at a temperature of 1,198 degs. Fahr. It seemed to him (Mr. Brown) that some attempt might be made to reconcile this difference of something like 2,700 degs. It might be that the difference was due to Messrs. Meyer and Münch's experiments being made with marsh-gas and coal-gas and oxygen, and not with marsh-gas and coal-gas and air.

Dr. P. P. Bedson said with regard to the difference in temperature of ignition coal-gas and air and marsh-gas and air as given by the French Commission and as observed in the experiments of Messrs. Meyer and Freyer and by Messrs. Meyer and Münch, that the latter experiments were quoted in the report now under discussion as being the most recent results on the subject. Prof. Meyer had used oxygen and not air in his experiments, but that would not make the difference which Mr. Brown had brought out by quoting the results of the French Commission. He thought they might accept the results obtained by Prof. Meyer in his experiments as reliable, because that gentleman had paid very considerable attention to this matter, and had used in the measurements of temperature some of the most recent and most perfect devices for recording temperatures. He (Dr. Bedson) would be therefore inclined to accept his results as conclusive and as material upon which to base their conclusions. Mr. Hall had referred to the varieties of pit-gas, and from what they knew of the gases occluded by coal and enclosed in coal-dust they would no doubt be ready to admit that a difference must exist in the gases met with in coal-mines. One would expect that fire-damp from some mines would contain not only marsh-gas but some of the higher members of the series to which marsh-gas belonged, and other specimens of fire-damp would no doubt be found which contained hydrogen. In the Wigan district a gas was met with, known as "sharp gas," which he thought contained not only marsh-gas but a considerable percentage of olefiant gas. The mode of measuring the force of explosives in the leaden cube was as follows:—The volume of the cavity created by the force of the explosion was measured by means of water. He might add that in estimating the value of any explosive it was necessary to take into consideration the safety of the fumes which the explosive might produce on detonation, and it had been ably demonstrated by Mr. Orsman† that carbonite developed a considerable quantity of combustible gases, which would make the use of carbonite a source of considerable danger, requiring special ventilation for the removal of the carbon monoxide and other gases so produced.

* Page 76. † *Trans. Fed. Inst.*, vol. iii., page 94.

Mr. J. L. Hedley (H.M. Inspector of Mines) hoped that the paper would be very thoroughly examined and criticized. It should, however, be remembered that the Committee had only given absolute facts, with the exception of the pages which contained the conclusions which had been derived from the facts. With reference to Mr. Steavenson's suggestions as to experiments with gunpowder in gaseous mixtures, he might point out that throughout the experiments the mixtures had been tested at intervals with gunpowder and always with the same result, namely, that if there was an explosive mixture of air and gas an explosion was produced. If the mixture was not explosive, they merely got an elongation of the flame of the shot: the results were invariably the same, and the effects so plain that the Committee had not thought it necessary to include them in their report. This remark applied to both pit-gas and coal-gas. He was glad that Mr. Hall had spoken as he had of the possibility of obtaining assistance from public funds. The experiments conducted by this Institute were of the greatest possible importance, and it could not be expected that the members would devote their time and money year after year to them, but possibly some arrangement might be made by which the experimental station might be used in determining by practical experiments questions which might arise from time to time. The smallness of the charge of explosives was decided upon owing to the size of the cannon and the size of the bore. Had the charge been heavier, it would have been brought too near to what he might term the mouth of the shot-hole. Farther, if ignition of a gaseous mixture was produced by means of a small charge of explosive, they might reasonably conclude that they would also produce ignition with larger charges.

Mr. H. Bigg-Wither (Wigan) wrote that the last conclusion* was open to criticism, chiefly because it did not specify whether the missed charge of high explosive still contained the detonator. He (Mr. Bigg-Wither) could well imagine that it might be possible to detonate a high explosive containing nitro-glycerine by the method named, even if it did not contain a detonator; but under the same conditions a nitrate-of-ammonia explosive could certainly not be detonated. He very much doubted whether it could be taken as a certainty that even a detonator embedded in a nitrate-of-ammonia explosive would always be exploded by another charge with 8 inches of stemming intervening. He considered that this conclusion should be made a little more definite.

Mr. George Beneké (London) wrote that he had read with the

* *Report*, page 41.

keenest interest the report of the Flameless Explosives Committee, and congratulated the members on the care with which these experiments had been carried out in the public interest. He felt it his duty, however, to point out that, in his opinion, a grave error had been committed with regard to the weights of the various explosives employed. His experience was, that most of the explosives, such as roburite, bellite, ammonite, and securite, were tolerably safe when fired in charges weighing from 3½ to 4 ounces, with No. 6 or No. 7 detonators, when untamped, in inflammable mixtures of gas and air or coal-dust. Beyond 4 ounces, the charges nearly always ignited and exploded suspended coal-dust, or an inflammable mixture of air, gas, and coal-dust. He was forced, therefore, to the conclusion that the small charges of 1 to 1¼ ounces of explosives, which the Committee exploded with No. 6 detonators, were wholly insufficient to quench the flame produced by the discharge of the detonator, and only assisted in blowing that flame into the inflammable mixture, and so producing the frequent ignitions recorded. Very recently he had erected an experimental apparatus near Wigan, where explosive charges, weighing from 5 to 16 ounces—being the average weights of charges used in collieries—could be tested in the presence of an inflammable mixture of gas and air, or air, gas, and coal-dust. In addition, a steel cannon had been fixed, by means of which the actual strength of an explosive could be ascertained.

Mr. G. B. Forster (Newcastle-upon-Tyne) said that this was perhaps the most important committee which the Institute had appointed. They had appointed many committees, and had no doubt derived a great deal of benefit and knowledge from their reports, but he thought the members would agree with him that this was the most important work which the Institute had ever undertaken. It was especially important to this district, where hard coal was so often found, that they should have accurate knowledge as to the safety of the different explosives. No doubt, when the farther report of the Committee is issued, the members will be farther enlightened as to the nature of the different explosives and their effects on various mixtures of gas, coal-dust, etc. He had pleasure in proposing a hearty vote of thanks to the Committee for the indefatigable industry and intelligence with which they had, at great inconvenience to themselves, devoted their time and attention to this subject.

Mr. J. B. Simpson, in seconding the proposal, said that, as a Mining Institute, they ought to do all that could be done to farther the extension of the experiments, and to endeavour to obtain help from H.M. Treasury or the County Councils if possible.

The PRESIDENT, in putting the motion to the meeting, said that the importance of the subject afforded sufficient ground for appealing for funds to H.M. Treasury or to the County Councils.

The vote of thanks was carried with acclamation.

Mr. J. L. HEDLEY acknowledged the vote of thanks in the absence of the Chairman of the Committee. He said that the Committee had completed a farther series of experiments with air and coal-dust alone, and hoped shortly to present a preliminary report thereon. They were now busy upon experiments with gas and coal-dust, but it must be borne in mind that only a very few experiments could be made in one day, and the members must give them credit for getting on with the work as quickly as possible. He was sure that the members of the Committee would feel gratified at the manner in which the report had been received.

Mr. A. L. STEAVENSON then moved a vote of thanks to Mr. A. C. Kayll for the skill, attention, and time that he had devoted to the work of the Committee.

The motion was seconded by the CHAIRMAN, and briefly responded to by Mr. KAYLL.

The meeting then terminated.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,

DECEMBER 8TH, 1894.

MR. THOMAS DOUGLAS, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council of that day.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. G. A. DENNY, Mining Engineer, Farm Tusschenby, Denny Dalton Gold Fields, Vryheid District, Transvaal.

Mr. THOMAS GILBERT DOBB, Mining Engineer, Derby Terrace, Hindley, near Wigan, Lancashire.

Mr. EDGAR TOM GARDINER, Mechanical Engineer, 8, South View Terrace, Bishop Auckland.

Prof. EDWARD HULL, Consulting Geologist, 20, Arundel Gardens, London, W.; and 4, Fenchurch Avenue, London, E.C.

Mr. JOHN MURRAY, General Manager, Raneegunge Coal Association, Limited, Giridih, India.

Mr. ALEXANDER ROSS, Manager, Wallsend Colliery, Newcastle, New South Wales.

Mr. FREDERICK AUGUSTUS THOMPSON, Mining Engineer, Broad Street House, London, E.C.

ASSOCIATE MEMBERS—

Mr. JAMES DODDS, Pearson and Knowles' Coal and Iron Company, Limited, Dallam and Bewsey Forges, Warrington.

Mr. F. GILLMAN, Gartenstrasse 1, Freiburg, Baden, Germany.

Mr. GEORGE ERNEST GREGSON, Land Agent, and Land and Mine Surveyor, 11, Chapel Street, Preston.

Mr. CHARLES ALBERT SMITH, Ropemakers' Representative, 20, Alexandra Place, Newcastle-upon-Tyne.

ASSOCIATES—

Mr. GEORGE ELTRINGHAM, Master Shifter, Shiremoor Colliery, Newcastle-upon-Tyne.

Mr. JOHN HARRISON, Under-manager, Ashington Colliery, Northumberland.

Mr. ROBERT LINDAY, Colliery Surveyor, Bishop Auckland.

Mr. JOHN HENRY MILLER, Colliery Surveyor, South Hetton, Sunderland.

STUDENTS—

Mr. WALTER NEWTON DREW, Articled Pupil, Thorncliffe Collieries, near Sheffield.

Mr. WILLIAM DENHAM HARBIT. Mining Student, 32, High Street, Wallsend.

Mr. JOSEPH HENRY SHERWEN, Mining Student, Marina Terrace, Hensingham, Whitehaven.

The following gentlemen were nominated for election :—

HONORARY MEMBER—

Rev. HENRY PALIN GURNEY, Principal of the Durham College of Science, Newcastle-upon-Tyne.

MEMBERS—

Mr. BASIL JOHN ATTERBURY, Mining Engineer, 18, Eldon Street, London, E.C.

Mr. WILLIAM BIBBY, Manager of the Raub Australian Gold Mining Co., Limited, Raub, Pahang, Malay Peninsula.

Mr. HARRIS BIGG-WITHER, General Manager of the Roburite Explosives Co., Limited, 10, Swinley Road, Wigan, Lancashire.

Mr. GEORGE BOOLE, Mining Engineer and Colliery Manager, Rainford, near St. Helens, Lancashire.

Mr. HENRY HUNTER CAMPBELL, Land and Mine Surveyor, and Mining Engineer, Sutton Hall, St. Helens, Lancashire.

Mr. JOHN FLINT, Colliery Manager, Broomhill Colliery, Acklington, Northumberland.

Mr. WILLIAM KENNEDY, Consulting Geologist and Engineer, Austin, Texas, United States of America.

Mr. LLOYD WILSON, Colliery Managing Director and Engineer, Flimby Colliery, Maryport.

ASSOCIATE MEMBERS—

Mr. JOHN S. BOLTON, Electrical Engineer, 78, Brighton Grove, Newcastle-upon-Tyne.

Sir GEORGE WILLIAM ELLIOT, Bart., M.P., 16, Great George Street, Westminster, London, S.W.

Mr. GEORGE B. SAUNDERS, Chemical Agent, etc., c/o Messrs. Dawson, Saunders, & Todd, Maritime Buildings, Newcastle-upon-Tyne.

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Mr. HENRY DUNFORD COWAN, Mining Student, Elswick Collieries, Newcastle-upon-Tyne.

Mr. JAMES BERTRAM SAMPLE, Mining Student, South Tanfield Colliery, Stanley, R.S.O., County Durham.

Mr. THOMAS DOUGLAS delivered the following Presidential Address :—

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Mr. THOMAS DOUGLAS delivered the following Presidential Address :—

PRESIDENTIAL ADDRESS.

By THOMAS DOUGLAS.

I appreciate and thank you for the honour which you confer upon me in electing me your President. In accepting the position and occupying the chair so ably filled by men eminent in the professions of mining and engineering who have preceded me, I can only hope to do so successfully by the aid of the Council, and by that of every member of the Institute. On this support I feel sure that I can confidently rely.

The history of the Institute has been so frequently written by Past-Presidents that I shall but very briefly refer to it. Having been connected with it from its very commencement in 1852 until the present time, I am well able to speak of the earnestness that characterized its early promoters and of the aims and hopes expressed by them in regard to it. In nowise have their expectations been disappointed. How strongly our esteemed first President, Mr. Nicholas Wood, and until his death in 1865, its continuing President, felt the necessity of such an Institution and foreshadowed its aims is well seen by the views expressed in the inaugural address delivered by him on September 3rd, 1852.

It was a valuable suggestion made at an early period, and no doubt in the mind of Mr. Wood when he gave the address referred to, that efforts should be made to amalgamate with any other institution or society of the United Kingdom, having for its object the prevention of accidents in mines.

Sir George Elliot in 1868, and Mr. John Daglish in 1886, in their Presidential addresses, and Mr. Theophilus Wood Bunning (for many years and until shortly before his death the valued secretary of our Institute), in a paper read by him in 1887, all strongly urged the desirability of such a combination; thus was brought about in 1889, a Federation, the object of which was to include all "societies interested in mining, metallurgy, engineering, and their allied industries."

The Federated Institution of Mining Engineers now comprises six institutes, with over 2,200 members, and I trust that during the present financial year other kindred societies not yet associated may be added.

The present number of Members, Associates, and Students in the North of England Institute of Mining and Mechanical Engineers is 791, showing an increase of 73 over the previous year.

I would draw special attention to the encouragement now offered by the Institute to the large class of under-viewers, under-managers, colliery engineers, students, and others who by a yearly subscription of one guinea are admitted as Associates or Students. I would impress upon every class the value and importance of taking advantage of this arrangement under which they would be entitled to consult the library, receive the *Transactions*, attend the meetings, and assist in the discussions. Already some have so joined, but the number is capable of very great extension, and members can do much towards this end by bringing the subject more prominently before the classes indicated.

I have on more than one occasion alluded to the desirability also of more distinctly urging the Institute's claims for support upon the owners of collieries and royalties. We are glad to record an increase in the number (now 22) of those who are already subscribers. We have, I think, peculiar claims upon these gentlemen. The expense incurred in carrying on the needful experiments, whereby such experience is gained as may lead to increased safety and economy in working mines, is very large, and colliery owners must be very greatly benefited thereby.

The "Explosives Committee" are now engaged in important experiments, which could not have been carried out had not the Institute received substantial aid from the Coal Trade Associations and from other bodies.

When we remember the responsibilities that attach to the position of a mining engineer, the lives that so largely depend upon his careful supervision and forethought, the depths to which shafts are now sunk, and the distance to which the ramification of the mines extend, it is obvious that men can only now occupy such positions with credit whose education and training have been of a thoroughly practical and scientific character.

Fortunately the opportunities for obtaining such instruction and experience are now materially enlarged.

Science classes have been established in every mining district—that admirable institution, the Durham College of Science, towards the establishment of which in our midst we have been much indebted to members of this Institute, has opened wide its doors to us, and its professors assist largely in our deliberations; whilst County Councils and Guilds by grants and scholarships enable deserving students, at small expense, to take advantage of the means now placed within the reach of all.

On the shelves of the library in the Wood Memorial Hall we find some 8,000 volumes, in which we may glean the information and

experience gathered up by men eminent in the profession from all parts of the world, and on every subject connected with mines and mining.

A paper, written by Prof. Merivale, which appeared in the *Transactions* of The Federated Institution of Mining Engineers,* in reference to the education of mining students, is worthy of attention by young men proposing to enter the profession.

I need not remind you that our object is, in the first place, to aim at increased safety for the lives of the army of workers engaged in or about the 3,383 mines of the United Kingdom, at which, according to the (1893) reports of the Inspectors of Mines, 683,008 persons were engaged, and from which 175,236,857 tons of minerals were extracted during the past year.

The farther information furnished in these valuable reports indicates the character of the accidents that have resulted in death.

In 1893, the deaths that occurred were 1,060.

Of this number 160 or 15·10	per cent.	were caused by explosion;
412 or 38·89	"	" falls;
103 or 9·70	"	occurred in shafts;
29 or 2·73	"	were caused by explosives or by suffocation;
131 or 12·36	"	" tubs or on engine-planes;
105 or 9·90	"	occurred from sundry causes;†
120 or 11·32	"	" on the surface.

During the ten years previous to 1893, the deaths averaged 1,032 per year.

Of which 147 or 11·24	per cent.	were caused by explosions;
460 or 44·57	"	" falls;
88 or 8·53	"	occurred in shafts;
231 or 22·38	"	" from sundry causes;
106 or 10·28	"	" on the surface.

The average death-rate, which for the ten years previous to 1883 was 2·243 per 1,000 persons employed, or 7·420 per 1,000,000 tons of output, sunk during the succeeding ten years to 1·806 per 1,000 persons employed, or 5·654 per 1,000,000 tons of output, whilst in 1893, it was 1·552 per 1,000 persons employed, or 6·049 per 1,000,000 tons of output. The highest death-rate in any inspector's district was 2·638, and the lowest 0·797 per 1,000 persons employed, and 13·369 and 3·212 respectively per 1,000,000 tons of output.

From 1851 to 1854, I believe the deaths from explosions amounted to 25 per cent. of the total deaths, the average death-rate being 4·54 per 1,000 persons employed, or 16 per 1,000,000 tons of output.

* Vol. v., page 623.

† A total of 265 deaths, or 24·99 per cent. from sundry causes underground.

In view of the great differences seen to exist in the death-rate between one inspector's district and another, it would be of value to elicit the precise conditions under which the respective districts are worked, so as to account if possible for these differences.

Whilst from time to time we are startled and shocked by the terrible mining catastrophes caused by explosions that unfortunately still occur, as so lately at the Albion colliery in South Wales, we yet notice how much larger is the proportion of the deaths from other causes. In reference to these I cannot doubt that with increased care the number will be largely reduced. To the marked and increasing intelligence of our workmen themselves, and to the ability and vigilance of our managers and over-lookers, assisted so largely as they all must be by Institutions such as our own, I now look, far more than to legislative enactments or further Government inspection, for a material reduction in all classes of accidents.

Much attention has lately been directed to the subject of "accidents in mines," and especially as to the part that coal-dust may take in causing them, and reports by Commissions in our own country and in those of France, Prussia, and Austria have been issued in reference to them.

During the present year an English Commission appointed "to enquire into the effects of coal-dust in originating or extending explosions in mines, whether alone or in conjunction with fire-damp," has issued its final report, and on the like subject, or bearing thereon, have papers been read to the members by Professor Bedson, Mr. McConnell, Mr. Blackett, and others, and previously by Professor Marreco, Mr. W. Cochrane, and the late Mr. D. P. Morison.

It is difficult to assume, however complete any apparatus may have been by means of which experiments on the subject have been made, that the precise conditions that prevail in a working mine can on all points be truly represented in such experiments, yet all, I think, concur in maintaining that fire-damp, present in even small quantities and not otherwise dangerous, becomes more or less dangerous in the presence of coal-dust.

Glancing over these reports I gather from them :—

That Messrs. Mallard and Le Chatelier, members of the French Fire-damp Commission, in 1882, rejected the theory that coal-dust alone could be the cause of any serious danger, or that any colliery explosion of importance could be attributed, with any probability, to the action of coal-dust.

That the Prussian Fire-damp Commission in 1887 came to the conclusion that the presence of coal-dust, in the complete absence of fire-damp,

gave rise generally to an elongation or propagation of the flame projected by a blown-out shot of limited extent, however far the deposits of dust may extend in the mine-roads; but that there were certain descriptions of coal-dust, which if ignited by a blown-out shot, would not only continue to carry on the flame even to distances much beyond the confines of the dust deposits, but would also give rise to explosive results in the entire absence of fire-damp, which in character and effects were similar to those produced with some other dusts in air containing 7 per cent. of fire-damp.

That the English Royal Commission in their report of 1886 on Accidents in Mines seems to be satisfied that a blown-out shot, where highly inflammable coal-dust exists in great abundance, may, even in the entire absence of fire-damp, possibly give rise to violent explosion, or at any rate be followed by the propagation of flame over considerable areas, and even by the communication of flame to distant workings, where explosive gas-mixtures or dust-deposits in association with non-explosive gas-mixtures exist.

That the Austrian Fire-damp Commission in 1891 having made a large number of experiments with a variety of dusts, found that, without any admixture of fire-damp, nearly all kinds of coal-dust were ignited by a cartridge of 3½ ounces (100 grammes) of dynamite lying unconfined, while many notoriously dangerous gases were less inflammable than other less dangerous ones, the fineness of the dust greatly increasing its sensitiveness and danger.

With the information afforded by the reports alluded to, and by the large body of evidence gathered, the English Royal Commission on "Explosions from Coal-dust in Mines," issued a report in June last. In it is expressed the opinion that a blown-out shot may under certain conditions set up a dangerous explosion, even where fire-damp is either not present at all, or only in infinitesimal quantities; but that in order to set up an explosion there must be a combination of circumstances which probably rarely occurs in the practical working of a mine. Thus the dust must be of sufficient purity, fineness, and dryness to be easily raised and to possess explosive qualities, and in sufficient quantities at the place where and at the time when a blown-out shot occurs. The shot-flame must be of considerable size and intensity, and must be propelled into the dust with great force. The position of the shot is also likely to affect the result. An explosion once initiated may, by the presence of coal-dust, be greatly intensified and extended over large areas.

The conclusions arrived at by the Commissioners I give in their own words. They are :—

The danger of explosion in a mine in which gas exists, even in very small quantities, is greatly increased by the presence of coal-dust.

A gas explosion in a fiery mine may be intensified, and carried on indefinitely, by coal-dust raised by the explosion itself.

Coal-dust alone, without the presence of any gas at all, may cause a dangerous explosion if ignited by a blown-out shot or other violent inflammation. To produce such a result, however, the conditions must be exceptional, and are only likely to be produced on rare occasions.

Different dusts are inflammable and consequently dangerous, in varying degrees; but it cannot be said with absolute certainty that any dust is entirely free from risk.

There appears to be no probability that a dangerous explosion of coal-dust alone could ever be produced in a mine by a naked light or ordinary flame.

I do not know that any of us will take very serious objection to these conclusions. There appears to me in them a certain amount of indefiniteness or uncertainty, suggesting that much farther consideration of the subject is still needed.

With reference to the question of "explosives," to the consideration of which our members, no doubt, will now give considerable attention, I would refer them to a paper by Mr. A. C. Kayll in last year's volume, giving a definition of the various mining explosives.* Many of these are already in daily use in our mines, and the experience gained by members using them placed on record would be valuable.

I hope the Home Office will, as I think it should, with the means at its disposal, take up the question and stamp with its authority such explosives as it finds can with safety be used under varying and, if possible, any circumstances.

At the present time a committee of the Institute, specially appointed, associated with which are the Inspectors of Mines of this mining district, is engaged in a series of experiments on explosives. A first report has just been placed in your hands, and furnishes a valuable contribution to our knowledge of the subject.

While desiring to limit as far as possible the use of explosives, yet to prohibit the use of gunpowder in all coal-mines, or of high explosives in any save in such as produce dust of a very exceptional character, would involve a cost at very many of our collieries (where the blasting of stone constitutes so considerable a part of their work) which they would without some considerable compensating advantage be unable to bear.

The Commission, however, seem unprepared to suggest that such a prohibition should be imposed in any case, save only after a full enquiry into the circumstances of the individual mine concerned.

* *Trans. Fed. Inst.*, vol. vi., page 346.

In view of the full discussion that will doubtless take place on this large and important subject, and of the legislation evidently foreshadowed, I will not further pursue the subject. A careful review, meanwhile, of the Government's reports alluded to, the valuable papers that appear on the subject in our *Transactions*, and of the complete report of the Explosives' Committee when issued, will help us to enter upon the discussion of accidents in mines with a greater hope of arriving at satisfactory conclusions.

We are indebted to Prof. Clowes and to Mr. A. H. Stokes for bringing to our notice their hydrogen and alcohol lamps for testing and estimating small percentages of inflammable gas, the presence of which would not be detected by any of our ordinary safety-lamps.

Fan ventilation up to date has been almost exhaustively treated on by our members. It would be a farther valuable contribution if those members who have erected what I may term "helping-up" fans underground would give the members the benefit of the experience derived from their application. I know that several members have such fans placed at considerable distances from the shafts, with the view of saving large outlays for farther sinking in order to secure increased ventilation. Excepting one by Mr. A. L. Steavenson, I am not aware that any other paper has been written on this subject.

I could have wished that greater progress had been made towards the working of coal by machinery. Many trials have been made with various machines, and with good results, but as yet there has been no general application of them. The difficulty and expense of providing and transmitting the needed power for driving them to remote distances has no doubt operated to delay progress.

If our thin seams are to be worked, the attention of mining and mechanical engineers must be directed to this subject. By the aid of funds for the purpose subscribed by colliery owners and others interested, a committee of suitable persons entering upon an enquiry would, I think, at any rate materially assist in exciting interest on the subject, and lead to some useful and practical result. Electricity will materially assist in getting rid of some of the difficulties alluded to, and already we are glad to note the rapid strides it is making in and about mines, carried readily and to remote distances for hauling, pumping, and lighting purposes. It will also, I think, lead to the introduction of locomotive traction under ground, as to which no progress seems to have been made since Mr. W. Lishman a few years ago introduced his air-locomotive at the Newbottle colliery.

We are indebted to the writers of several papers on electricity, printed in the *Transactions*, for giving their experience already gained from its use. We shall continue no doubt to receive enlarged information that will enable a judgment to be formed as to its suitability and economy for underground work under various circumstances.

Considerable attention has of late, as our *Transactions* show, been directed to improving the machinery for screening and cleaning coal. I might mention that during the past year the owners of Evenwood collieries have erected a very large and complete Luhrig plant for automatically sorting and washing coal. The system has been described by Mr. John Hogg and Mr. G. B. Walker.* As yet no other colliery in either Northumberland or Durham has adopted the system. Though it has involved a very large expenditure, I believe the colliery owners are perfectly satisfied with the results obtained, and may, I hope, be willing to allow its inspection and give the members full information as to its advantages and economies.

I shall not detain you longer, but can only add, in conclusion, that mining engineers are looking anxiously for whatever can be devised for securing increased economy in the cost of production. The thicker coal-seams are being rapidly exhausted, while others remain equal in quality but of greatly reduced section.

Over a somewhat large area, I have found that whereas twelve years ago but little if any coal was being then worked out of seams under 3 feet in thickness, yet out of the same area fully 22 per cent. is now being worked from seams under 26 inches in thickness, and this proportion is becoming yearly an increasing one.

The change, to a greater or less extent, prevails throughout the northern counties and elsewhere. It becomes, therefore, a serious problem for mining engineers to solve: namely, how best to meet so serious a falling off in section, involving as it does so largely increased cost.

To each member we look for giving the Institute the value of his experience, and for bringing to its notice whatever may be so found by him to lead towards this solution.

The PRESIDENT, in conclusion, said he was startled when, a few years ago, Mr. Simpson stated in his presidential address that of the original members of the Institute only seven remained. Of those who were

* *Trans. Fed. Inst.*, vol. vi., page 393; and vol. vii., page 392.

members of the Institute in 1852 only four now remained, and he was pleased to know that of these there was one whom they looked upon as their veteran mining engineer, and who as they hoped would yet be spared for many years to take an interest in the Institute—he referred to their friend Mr. William Armstrong.

Mr. J. B. SIMPSON proposed a vote of thanks to the President for his able and valuable address. A year or two soon passed, and there did not seem much that was fresh to record, but still Presidential addresses had the advantage of bringing continually before the members of the Institute both the wants and the difficulties in mining and the means of securing safety and economy; and their thanks were due to Mr. Douglas for the able way in which he had treated the various subjects of his address.

Mr. W. O. WOOD said that it had frequently been a matter of wonder to him that their Presidents from time to time had been able to compass fresh subjects, and they must all admit that the present address lacked nothing in freshness and novelty, and must prove exceedingly valuable to all who had listened to it. He then seconded the vote of thanks.

The vote of thanks was heartily adopted, and briefly acknowledged by the President.

Mr. ALEXANDER SIEMENS (London) read the following paper on "Electric Transmission of Power":—

ELECTRIC TRANSMISSION OF POWER.

BY ALEXANDER SIEMENS.

At a meeting of the Iron and Steel Institute held in Newcastle-upon-Tyne in the year 1877, Sir William Siemens discussed the possibilities of transmitting power to a distance by means of the electric current, and called particular attention to the feasibility of utilizing the power running to waste at the Niagara Falls, which he had visited during the preceding year.

If the writer is not mistaken, it was this address which induced Lord Armstrong, a distinguished citizen of Newcastle-upon-Tyne, and a past-president of your Institute, to put up at Cragside a small electric plant for utilizing a waterfall in his grounds for lighting purposes at night and for motive power during the day.

Not long afterwards Sir William Siemens replaced a steam-engine by an electric motor for driving a pump near his country-house at Tunbridge Wells, and also employed the current for driving various farm-implements, in addition to the lighting of the house.

These applications of electric transmission were perfectly successful, and might have been imitated in many country-houses and elsewhere, but for a time lighting absorbed the attention of electrical engineers, and it is only lately that the transmission of power has been taken up in earnest.

First of all, electric tramways were developed, and their rapid extension is sufficient proof that reliable electric motors can be built which will work under very trying circumstances without giving trouble.

Most of the members will be acquainted with the papers read by Mr. Selby Bigge before this Institute* and the Iron and Steel Institute,† in which the subject is treated in a general manner, and some interesting examples are mentioned.

More recently, Mr. Richardson has dealt with the same subject in his presidential address to the North-East Coast Institution of Engineers and Shipbuilders, which has given rise to an interesting discussion.‡

* "The Practical Transmission of Power by Electricity," etc., *Trans. Fed. Inst.*, vol. iii., page 278.

† "Electricity as a Motive Power in the Iron and Steel Industries," *Journal of the Iron and Steel Institute*, 1894, vol. xlv., page 252.

‡ *Trans.*, vol. xi., page 13.

Under these circumstances it would be tedious if the writer repeated a description of the general features of electric transmission, and gave again the reasons for expecting economic advantages from the adoption of electric motors in the place of scattered steam-engines.

There is one point, however, which has not received, in the papers mentioned, the attention that it deserves, and that is the size of the motors employed.

One of the characteristics of an electric motor is that the current passing through it depends on the work which it is called upon to do, as the writer showed in a lecture before the Society of Arts in 1883.* The consequence is that, if the motor be only just powerful enough for its regular work, any accidental increase in its load will cause a current to pass, which may seriously damage the motor. This, in fact, is almost the only quality in which an electric motor compares unfavourably with other mechanical motors. If these are overloaded, they run more slowly or stop, but an electric motor is liable to destruction. Fortunately another quality of electric motors counteracts this disadvantage, and that is their comparative great efficiency at a diminished load. It is therefore advisable, for economic reasons, to employ comparatively large motors, although the first cost of an installation is increased thereby, but the absence of repairs will very soon repay the extra outlay.

Exactly the same result has been experienced with dynamos for lighting purposes, which at first were always worked to their full capacity, in order to obtain a large output with the smallest possible quantity of materials. You will find, for instance, that Prof. Tyndall, in his report to the Trinity House on electric lighting experiments at the South Foreland, lays particular stress on this point, and considers the lightest machine the best. When these dynamos were put on regular duty they worked for a few months very well, but afterwards their insulation broke down, and they gave so much trouble that they had to be replaced.

It would be a great pity if the same mistake were repeated with electric motors, and if any of the members contemplated the adoption of electric transmission in their works they should not forget to compare the sizes of the dynamos proposed as well as their cost. The latter alone is no criterion whatever.

The writer's principal object is to lay before the members some results of the adoption of the electric transmission of power at the Woolwich works of Messrs. Siemens Brothers & Co., where the change was commenced about two years ago, and is even now not quite completed.

* *Journal of the Society of Arts*, 1883, vol. xxxi., page 531.

The diagram (Fig. 1, Plate XIV.) shows a plan of the works, which cover about six acres of ground.

At the central station 12A, there are five boilers working at a pressure of 130 pounds per square inch, of the "gun-boat" type, *i.e.*, two-flued multitubular boilers, each 18 feet long and 9 feet in diameter. They are hand-stoked, and supply steam to the machinery of the central station, to the steam-engines driving the guttapercha shop, and for heating purposes.

Condensers are placed on the roof of the boiler-house, each sufficient for 25 indicated horse-power. These condensers consist of two cylinders, one placed inside the other, forming an annular space into which the steam passes from the engines, while cold water is trickling down the outside of the larger and the inside of the smaller cylinder. The condensing water is used to feed the boilers and to supply the guttapercha and indiarubber washing-tanks, and the condensed steam is allowed to run to waste.

In the engine room 12, which measures 42 feet by 30 feet, there are four steam dynamos, each capable of giving a current of 1,500 ampères at 120 volts pressure, when running at 350 revolutions per minute. All four dynamos are exactly alike, being two polar drum armature machines of the Siemens H.B. 24/36 type, shunt-wound, and fitted with switch and resistances for varying the exciting current by hand. Three of the dynamos are driven by three Willans III. compound condensing single-acting engines, and the fourth is coupled to a Belliss compound condensing double-acting engine (Fig. 2, Plate XIV.).

The four generating sets are coupled in parallel to an omnibus bar, with ampère indicators showing how much current each set is giving, and from this bar the main cables are laid to the various departments, a safety-fuze and an indicator being fitted in each circuit. Provision is also made on the switch-board for coupling two of the generating sets in series, when a current of 240 volts pressure is required at any part of the works (Fig. 3, Plate XIV.). The return cables are also all joined to one bar, and from this bar the current passes through a registering meter before it returns to the dynamos (Fig. 4, Plate XIV.). In this way an exact record is kept of the current generated at the central station. The total length of cable laid between the switch-board in the engine-room and the distributing boards in the various departments is a little over 18,000 feet, the area of the cross section of the copper conductor varying from $\frac{1}{4}$ to $1\frac{1}{2}$ square inches.

Each department has its distributing-board to which the current is brought from the central station by one or more main cables; it is fitted with a registering-meter, and with fuzes for the branch cables which lead to the various motors in the department (Fig. 5, Plate XIV.).

All the main cables have the copper conductor insulated by impregnated jute, covered with lead, which in its turn is protected by tarred jute and steel ribbon, again covered with jute and compound. These cables are laid directly into the ground without farther protection, and have never given any trouble.

Owing to the rules of the London County Council, each motor is completely enclosed, and by no means readily accessible. Some motors are quite cased in with sheet iron, so that nobody may come in contact with moving parts. In other instances, an iron framing covered with iron netting is put round the motor, and this arrangement has the advantage of permitting a free circulation of air.

At the present time, 72 motors are in use, varying in size from 100 to one-sixth of a brake horse-power, and capable of giving a total of 1,407⅙ brake horse-power.

The output of the central station is 1,200 indicated horse-power, which (with an efficiency of 86 per cent.) gives 1,130 electrical horse-power available at the central station, or, roughly, 1,000 brake horse-power at the motors in the workshops.

With regard to these figures, it should be remembered that the whole plant is capable of producing from 25 to 30 per cent. more output, when required for a few hours, without any danger of straining any part of it, and this is the safeguard to which the author has already called attention, and which ensures the satisfactory working of such an installation.

Before the electric transmission was introduced, eighteen steam engines were employed, capable of yielding altogether 1,446 indicated horse-power. These correspond to about 1,150 brake horse-power, then available for driving machinery. Seven of the old steam-engines, giving about 380 brake horse-power, are still in use, so that the total power now at disposal for motive purposes is 1,787 brake horse-power, while, in addition, the central station furnishes current for 72 arc-lights and about 1,600 sixteen candle-power incandescent lights.

A comparison of these figures will at once show that the works have been considerably extended since the first steam-dynamo was started, on June 20th, 1892, and for this reason it has been rather difficult to find out how the cost of power at the present time compares with that of working steam-engines alone.

Another circumstance which made such an enquiry complicated was, that the work on a large cable contract this year increased all expenses of fuel and labour to such an extent, that the preceding years cannot be compared with it in order to determine the exact saving that has been effected.

In former years, cable work of equal duration increased our consumption of coal by nearly 5,000 tons, but this year the increase has not been more than about 2,000 tons, so that an actual saving appears to have been effected of about 3,000 tons of coal.

The steam-engines and boilers of the old installation were tended by ten stokers and nine engine-drivers, while at the present time eight stokers are employed, of whom three attend to the old boilers still in use, and five engine-drivers, three of whom attend to the old engines.

The electrical part of the machinery in the central station is attended to by one electrician and a boy, while the motors are attended to by the oilers of the various departments.

When the arrangements are completed, all auxiliary boilers will be abolished, and a farther saving of attendants will be effected.

As far as they go, these comparisons prove that the electric transmission has been economical, but in order to obtain satisfactory information as to the performance of the plant, a series of tests were conducted by the experiment department, under the direction of Dr. Eugin Obach, as follows :—

The boiler-tests and engine-tests were carried out separately in two series. The first series was intended to determine the weight of steam generated per pound of fuel, and this test extended over a month of ordinary working, and included all necessary coal for lighting up. The second series was intended to determine the weight of steam required by the engines, per Board of Trade unit delivered to the distributing bars of the central station switch-board. This was found by exhausting the engine under test into the main condenser, and measuring the overflow from the air-pump, taking care that no other water could mix with the overflow.

These engine-tests were subdivided again into two kinds :—(1) Running on steady artificial loads of about $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and full load; and (2) running on the ordinary day load.

The second set of tests was undertaken to see if a varying day-load required the same weight of steam per Board of Trade unit as a perfectly steady load giving the same output. This was found to be the case, the point obtained by the day-load test fell exactly on the curve obtained from the steady load tests (Fig. 6, Plate XV.).

As factors involved in the cost of generating a Board of Trade unit, the steam taken by all the auxiliary pumps had to be taken into account. This was done by condensing the steam exhausted from the feed-pump, air-pump, and circulating-pump, and weighing the water discharged. As

the feed-pump supplied water to all the boilers, only a part of its steam was taken in the proportion which the air-pump discharging from the condenser bore to the total feed-water.

Coal.—The coal was weighed out of the barges in quantities of 15 cwts. at a time; a reliable steel-yard was slung on the crane-hook and was compared from time to time with standard weights. A sample was taken from each skip, and all the samples were afterwards ground up and well mixed, thus affording a thoroughly representative sample of the coal for analysis.

Water.—The water was fed from a feed-water heater into a measuring-tank holding 6,270 pounds; this tank stood over a shallow supply-tank, and could be emptied into it through a 6 inches valve. The temperature of the feed-water was frequently taken.

The test was started with a perfectly clean stokehold floor, the furnaces having been supplied from a separate store of coals, which was locked up as soon as the use of the weighed coals was commenced. The water-levels in the gauge-glasses were marked, and the steam pressures and state of fires were noted.

A log-book was kept, with the following entries:—(1) Time of shift (eight hours); (2) name of person in charge of shift; (3) boilers in use; (4) amount of coal weighed into bunkers; (5) state of bunkers; (6) pounds of water fed during shift; (7) mean temperature of feed-water; (8) mean steam-pressure; and (9) water-level in feed-tank at end of shift.

At the end of the first week the boilers were worked down to the same condition as at starting, and all the coals used up, feed-water noted, etc., to form a check. Then the test was continued, and went on until the month was up, all the conditions being the same at the end.

Engines.—The engines and dynamos were run for five hours on each load, that is, four tests on each type of engine, eight tests in all on the steady loads.

Simultaneously, the auxiliary pumps, etc., were measured, and the electrical output of the dynamos was gauged.

The engines were indicated every half-hour, giving ten sets of diagrams for each load. To ensure simultaneous readings of the electrical instruments and indicators a whistle was blown.

Electrical Measurements.—The electric current was measured in two ways. (1) By three Siemens ammeters A53 type, which were frequently compared with the standards, in the positions in which they were used, and were set up in such a way as to have no disturbing effect on one another. The readings of these three instruments were adopted. (2) By

a large plate of german silver carrying the main current, and having its difference of potential measured at two points by a delicate galvanometer. The two methods described above gave very consistent results, particularly at the two lower loads.

The volts were measured by:—(1) A Siemens torsion-galvanometer, checked with the Clarke standard cell before and after all the tests, and found correct. (2) A Weston standard voltmeter. These two methods also agreed, the difference being quite negligible. The voltmeters were placed at a distance from any machines or cables carrying current. These readings were adopted.

To ensure the greatest possible accuracy in the efficiency tests, all the steam-engine indicator-springs were tested by an independent manufacturer, and a correction-table applied to the indicator-cards.

In making up the cost of a Board of Trade unit, the following items were included:—Coal, including cost of delivery to bunkers; water, auxiliary pumps, &c.; oil, waste, and sundry stores (for last six months); removal of ashes, engine-room drivers and machine-tenders, electrician and switch-board boy, stokers and repairs.

This cost only refers to the Board of Trade unit at the switch-board, and takes in no charges connected with the distribution-plant. The actual results obtained are stated below.

Boiler Efficiency—Boilers of gunboat type:—

	Square Feet.
Nos. 3 and 4 boilers, heating-surfaces—	
Tubes	1,033
Flame-boxes	222
Total	1,255
No. 5 boiler, heating-surfaces—	
Tubes	1,110
Flame-boxes	215
Total	1,325

The grate-area of boilers, Nos. 3, 4, and 5, was 41 square feet for each. The duration of test was 356⅓ hours. The total of boiler-hours was 988.

Nixon navigation coal was used, the mean thermal value of four samples being 14,221 British thermal units. The evaporative power at 212 degs. Fahr. was 14·65 pounds of water per pound of coal. The mean carbon value of the coal was 0·993. The coal burned per boiler per hour was 625 pounds, and per square foot of grate-area per hour, it was 15·25 pounds.

FIVE HOURS' TESTS OF A WILLANS III. COMPOUND CONDENSING ENGINE (No. 2), OF 300 INDICATED HORSE-POWER, COUPLED TO SIEMENS H.B. 24/36 DYNAMO, 1,500 AMPÈRES AND 120 VOLTS, AT 350 REVOLUTIONS PER MINUTE.

Experiment.	Indicated Horse-power.	Volts.	Ampères.	Watts.	Electric Horse-power.	Board of Trade Units.	Pounds of Coal per Hour per Indicated Horse-power.	Pounds of Coal per Hour per Electric Horse-power.	Pounds of Coal per Board of Trade Unit.	Pounds of Steam per Hour per Indicated Horse-power.	Pounds of Steam per Hour per Electric Horse-power.	Pounds of Steam per Board of Trade Unit.	Efficiency. Col. 5 / Col. 1.
													Per Cent.
1	95·75	120·7	376·2	45,407	60·87	227	2·29	3·945	5·28	20·5	35·2	47·15	63·6
2	149·2	120·05	712·3	85,511	114·6	427·5	2·35	3·06	4·10	21·0	27·3	36·6	76·8
3	209·8	119·75	1,106	132,443	177·5	662·2	2·24	2·656	3·55	20·03	23·7	31·7	84·6
4	268·9	118·2	1,459	172,453	231·2	862·3	2·18	2·545	3·41	19·5	22·7	30·45	86·0
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)

FIVE HOURS' TESTS OF A BELLISS COMPOUND CONDENSING ENGINE (No. 1), 300 INDICATED HORSE-POWER, COUPLED TO A SIEMENS H.B. 24/36 DYNAMO, 1,500 AMPÈRES AND 120 VOLTS, AT 350 REVOLUTIONS PER MINUTE.

Experiment.	Indicated Horse-power.	Volts.	Ampères.	Watts.	Electric Horse-power.	Board of Trade Units.	Pounds of Coal per Hour per Indicated Horse-power.	Pounds of Coal per Hour per Electric Horse-power.	Pounds of Coal per Board of Trade Unit.	Pounds of Steam per Hour per Indicated Horse-power.	Pounds of Steam per Hour per Electric Horse-power.	Pounds of Steam per Board of Trade Unit.	Efficiency. Col. 5 / Col. 1.
													Per Cent.
1	79·4	120·02	376·0	45,127	60·49	225·6	2·99	3·91	5·24	26·7	34·9	46·8	76
2	144·75	120·05	747·6	89,749	120·3	448·7	2·72	3·28	4·39	24·3	29·25	39·2	83·3
3	212·8	120·32	1,116·8	134,373	180·12	671·9	2·48	2·94	3·94	22·2	26·26	35·2	84·7
4	271·6	121·22	1,418·0	171,890	230·4	859·5	2·51	2·95	3·95	22·4	26·33	35·3	85·1
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)

The water evaporated per boiler per hour was 5,576 pounds. The weight of water evaporated per pound of coal (including coal used in lighting fires) into steam at a pressure of 127 pounds per square inch was 8·923 pounds. The weight of water evaporated per pound of coal from and at 212 degs. Fahr. was 10·083 pounds. The weight of water evaporated per square foot of total heating-surface per hour was 4·42 pounds. The weight of water evaporated per square foot of grate-area per hour was 136 pounds. If the coal used in lighting up be neglected, the evaporative efficiency becomes 9·16 pounds of water per pound of coal at a mean pressure of 127 pounds per square inch, and 10·35 pounds of water per pound of coal from and at 212 degs. Fahr.

The annexed experiments were made on steady loads (resistance frames):—

DAY-LOAD TESTS OF FIVE HOURS, THE VARIATION OF LOAD BEING ABOUT 15 PER CENT.

	Willans Engine, etc.		Belliss Engine, etc.
Mean current (ampères)	1,167	...	1,184
Mean pressure (volts)	121·83	...	126·38
Mean power (watts)	141,592	...	149,634
Mean electric horse-power	189·8	...	200·6
Board of Trade units	707·96	...	748·17
Weight of steam used per electric horse-power per hour (pounds)	23·39	...	26·2
Weight of steam used per Board of Trade unit (pounds)	31·35	...	35·1
Weight of coal used per electric horse-power per hour (pounds) ...	2·62	...	2·93
Weight of coal used per Board of Trade Unit (pounds)	3·51	...	3·93
Proportion of full load	0·778	...	0·789

These engines were not indicated, owing to the impossibility of taking simultaneous readings.

From these experiments, two diagrams have been prepared, one showing the steam-consumption per Board of Trade unit, per electric horse-power, and per indicated horse-power (Fig, 6); and the other the efficiency of the steam-dynamos (Fig. 7, Plate XV.).

It will be seen that the steam-consumption of the Belliss engine was greater than in the Willans, but it should be stated that this was the first engine of its kind ever built of that description, and that it has the worst position as far as the exhaust steam is concerned. On the other hand, the efficiency shows to greater advantage in the Belliss set, the dynamos being identical.

After the consumption of fuel and of water had been determined by these experiments, the value of the stores issued to the central station for the last six months was ascertained, together with the wages paid and the cost of the repairs done to the central station and to all the electric plant, including motors.

The out-put of the station had been at the rate of 1,797,120 Board of Trade units per annum, representing a load factor of 0·285. The actual cost per Board of Trade unit was, therefore, for the six months ending October 31st, 1894 :—

	Per Board of Trade Unit. Willans. Pence.		Per Board of Trade Unit. Belliss. Pence.
Coal (including cost of delivery and removal of ash), 17s. 5d. per ton. Willans, 3·41 lbs.; Belliss, 3·95 lbs. per Board of Trade unit	0·3180	...	0·3680
Water (7½d. per 1,000 gallons)	0·0228	...	0·0264
Stores, oil, waste, boiler-fluid, etc. (taken from last six months' consumption) ...	0·0416	...	0·0416
Wages, stokers, trimmers, drivers, labourers, electrical assistant (half-time), and switch-board boy	0·0977	...	0·0977
Steam for auxiliary pumps, feed (only 0·7 taken), air and circulating, water 0·003d., coal 0·026d.	0·0290	...	0·0290
Repairs to central station plant and motors	0·0802	...	0·0802
Total cost per Board of Trade unit ...	0·5893		0·6429
Total cost per electric horse-power per hour...	0·440		0·480

The cost for steam supplied to auxiliary pumps, etc., is too high, as there was only one set exhausting into the main condenser during the tests, and the steam of one circulating-pump and the air-pump was charged to this set: probably a very little more steam would suffice for the full working load on the condenser.

This cost is that of a Board of Trade unit at the switch-board in the central station. The loss of energy in the cables is not more than 5 per cent., and the average efficiency of the motor being taken at 90 per cent., the cost of a brake horse-power or 746 watts may therefore be taken at 0·515d. per hour.

No attendance has been charged to the motors, and the expense of oiling is very trifling, especially in motors fitted with Meneely bearings, of which a model was shown. Such bearings were applied to the three bearings of a Siemens H.B. 15/20 motor, developing about 40 brake horse-power at 360 revolutions per minute in driving part of the machines in the

lead-cable-sheathing shop. Two of the journals are $2\frac{3}{4}$ inches in diameter by $7\frac{3}{16}$ inches long, while the third is $3\frac{1}{4}$ inches in diameter by $6\frac{7}{16}$ inches long. During the first week's run, one of the roller-bearings got rather hot, but not sufficiently so to necessitate stopping the motor; and since that time, the beginning of July, 1893, they have all been running satisfactorily. The consumption of oil, after the first few weeks, was at the rate of one pint per month for the three bearings.

In order to make a comparison between the outlay for an electric plant, and for a steam-plant, the author has had a table prepared, showing the cost of the old steam-engines and boilers at Messrs. Siemens' works, together with the cost of foundations, erection, and of the chimneys. A statement, similarly, of the cost of the new boilers, of the pipe work, of the auxiliary engines, the condensers, the steam dynamos, the cables, motors, switches, and all accessories has been also prepared.

In the old steam-plant of 1,446 indicated horse-power, taking into account the long lengths of shafting that had to be driven, the author does not think that more than 60 per cent. or 867 brake horse-power, was really utilized. On the other hand, there are now 1,407 brake horse-power available at the motors, and 240 horse-power devoted to electric-lighting purposes.

The author does not wish to publish the exact costs, but the capital outlay per brake horse-power was 30 per cent. higher in the case of the old steam-plant, than for the present electric central station plant. Moreover the load factor, viz., the proportion of the actual output of the central station to the possible output, which, as stated above, is 0·285, shows that we can connect to the present generating-plant many more motors without much fear of overloading it.

There can therefore be little doubt that for new works, electric transmission of power is certainly more economical than the employment either of separate steam-engines or of transmission by belts or ropes.

Whether a change from the old system to electric transmission can be recommended depends entirely on local circumstances, and this question can only be ascertained by carefully weighing all the factors that come into play. Generally speaking, electric transmission is most applicable where power is wanted at a number of places scattered over the works, and especially in and about mines and collieries.

Such a case has lately been investigated by the writer's firm, and they have made an offer to replace various engines, exerting altogether about 800 brake horse-power, by an electric plant, comprising a central station similar to that at Messrs. Siemens' works, but having only three boilers

and three sets of steam-dynamos, all switches, cables, and motors to do the above work for a certain sum. By this conversion the colliery owner would save sufficient money, counting 15 per cent. of his outlay for interest and depreciation, to repay the outlay in ten years, or in other words the cost of working the plant for a year would be less than the present cost by an amount equal to 25 per cent. of the outlay.

These figures show that there is a wide field for successfully applying electric transmission of power, in works as well as in mines, where electric motors must be especially welcome, as they do their work without forming any bye-products that have to be dealt with by costly contrivances.

In these times of ever-increasing competition it is well worth while to utilize all advantages that science places at the disposal of industry, and anything that increases the amount of power at our disposal for each pound of fuel consumed, should meet with hearty support in this great centre of mining and industry.

Mr. A. SIEMENS supplemented his remarks by referring to the existing electric locomotives on the South London Subway. Messrs Siemens Brothers were asked to supply two locomotives (each carrying two motors) to be used in place of others which had not given entire satisfaction: and on their delivery considerable comment was made as to the great size of the motors. It was contended that it was an obstacle to the adoption of electric traction to put in motors like an elephant to do a donkey's work. But these motors being so very large for their work took very little current, and the heating of the armature was practically *nil*. After the first experimental run along the line, the engineers of the company applied thermometers to the armature, and were astonished to find that there was no perceptible increase of temperature. In regular working, it had been found that the Siemens locomotives did the work with 50 for which other locomotives required 80 ampères, the difference being due to the fact that the motors on the other locomotives were a little smaller, and consequently got hotter when in use. By adopting the larger size of motor, 40 per cent. of the current was saved, and this saving was worth considerably more than the interest on the difference of first cost. The Siemens locomotives had run over 60,000 miles without any repairs, and the first pair of brushes was still in use. He referred to this question because it was often contended that an electric motor frequently cost more in brushes than a steam engine did in coals. He (Mr. Siemens) suggested that if electric motive power were introduced into mines for hauling, etc., the same

mains might be used for lighting purposes. He was reminded that he was now speaking in Newcastle, and therefore instead of taking the price of coal (including the removal of ashes) at 17s. 6d.,* he might reduce it to one-third, say 5s. 10d. per ton. Under these circumstances, the cost of the Board of Trade unit would be: Willans engine, etc., 0·377d.; Belliss engine, etc., 0·390d.; and the cost of an electric horse-power, 0·28d. and 0·29d. respectively.

Mr. C. A. Parsons (Newcastle-upon-Tyne) wrote that he thought the members were very much indebted to Mr. Siemens for the valuable practical information contained in the paper. As far as he knew, it was the first reliable information which had been placed before the public with regard to the cost of transmission of electrical energy to short distances. It seemed to him that electric transmission was undoubtedly the cheapest and most economical method of distributing power to scattered or irregularly arranged works, and as such, one of its best fields would be to replace numerous small engines in existing works which had grown up bit by bit, as the requirements of business had necessitated additional departments and buildings. Whether it was the best means of distributing power in a new works where the buildings were compactly arranged seemed to be at the present time a matter of some doubt, as it could not be denied that the capital cost and the maintenance in motion of shafting and a small amount of belting would be less than that of an electrical installation of dynamos and motors and connecting-wires. It would be interesting to know the objects that Mr. Siemens had in view in adopting the form of condenser which he described, in preference to a cooling-pond and an ordinary surface-condenser. It would also be interesting to know what vacuum was obtained from these special condensers. The figures of steam consumption per electric horse-power were most interesting, as he believed that they were the first reliable independent tests that had been made with Willans and Belliss engines under ordinary working conditions. Mr. Siemens figures appeared to be somewhat higher than those obtained on special tests; this, however, he believed, was always the case, owing to small leakages and other losses which were present in steam machinery under ordinary working conditions. He (Mr. Parsons) had the pleasure of seeing Messrs. Kinoch's works at Birmingham recently, where each shop is worked by one electric motor driving several lines of shafting by belts, the current being generated from a central station. The buildings of this explosives factory are necessarily scattered, with a view of minimizing the danger from explo-

* *Trans. Fed. Inst.*, vol. viii., page 256.

sion, and consequently electrical transmission of power is there eminently suitable. There were many other manufactures in which similar applications of electricity could be used to advantage.

Mr. W. O. Wood asked Mr. Siemens to explain how it happened, in the case of the load suddenly being taken off, that the motor, instead of running away, automatically adjusted itself to the load and current, even when the generator was placed at some distance!

Mr. Henry Lawrence said that the author showed an economy of 30 per cent. in favour of the electric motor when compared with an ordinary steam engine for the same amount of work. He understood that Mr. Siemens in making his experiments did not take exactly what the dynamo and electric motor were doing but what they might do, and he did not think this was a fair method of comparing the horse-power obtained by the electric motor with that obtained by the ordinary steam engine. Again, the writer mentioned that if the machinery were cut off from the steam engine it would run away. If that were so, it must have been an old-fashioned engine and the engineman could not know his work, for with the Corliss type of engine and other similar engines he had suddenly thrown 300 horse-power off an engine without being able to detect a difference of two revolutions in its speed.

Mr. A. L. Steavenson said that the subject of electric-power transmission had been so frequently brought before the members that he hesitated to enter again into the discussion, but he thought it would hardly be fair to Mr. Siemens not to raise a few points for his consideration. He quite agreed with the remark that "Whether a change from the old system to electric transmission can be recommended depends entirely on local circumstances, and this question can only be ascertained by carefully weighing all the factors that come into play." It was hardly fair to compare an old works, where the engines had as it were dropped from the clouds, with pipes, probably uncovered, extending in all directions, with a new works erected with the experience of present knowledge on the subject. If, in comparison with Messrs. Siemens' works, he (Mr. Steavenson) were to take a similar works, and put down a new plant, using such motive power as he chose, he had strong doubts as to whether at the end of ten years the balance would be in favour of electricity. At the close of the paper the author stated that "these figures show that there is a wide field for successfully applying electric transmission of power in works as well as in mines." He (Mr. Steavenson) was inclined to join issue with the writer, for he had already on several occasions inculcated caution. With high pressures or low pressures there was the risk of fire. In roads

in mines wires might be covered, but they were left for many hours together, and if a short circuit occurred, the result was to ignite the timber and coal, a state of affairs which might have most serious consequences. He pointed out at the Newcastle meeting of the British Association that the special features of coal-mining required great caution in the use of electricity, the lowness of the seams necessitating the cables being placed within easy reach; and there was also the fact that it was dark, and a man might, without noticing what he was doing, make a false step, put out his hand, touch the cables, and receive a serious shock, or even be killed. Mr. W. H. Preece objected to this statement, and a discussion had arisen as to what he (Mr. Steavenson) really said. On September 24th, 1889, Mr. Preece wrote to the *Times*, and said that "what I did characterize as absolute nonsense was the reason which a mining engineer adduced against electrical currents for transmission of power in mines, viz., that a man who touched such a wire would be killed; such currents are invariably direct currents of low pressure, and are therefore quite safe." But in the *Electrical Review** there is a paragraph as to a fatal accident from this very cause as follows:—

On Thursday last, James M'Inulty was killed instantaneously by coming in contact with the electric haulage-apparatus in Bogside pit, belonging to the Lanemark Coal Company. While in the act of lifting a hutch, the side of his head touched a defective casing in which the electric wire runs, and stuck fast. Another miner caught hold of him, but was thrown off by the shock. Presently the driving engine was stopped, and the body of the man fell lifeless.

He was, therefore, not talking "absolute nonsense," and the paragraph proves that mining engineers should use electricity with great caution, and he had endeavoured to impress upon those who heard his remarks at the meeting of the British Association that whilst electricity was a good servant it was a dangerous master. His advice was when using electricity not to use high-tension or alternating currents. The question arose as to what was a safe current, and on this subject he might quote from the report of the Health Committee of New York (October 15th, 1889), where a large number of fatal accidents had occurred:—

It is our opinion, based upon our own experiments and authentic records, that an alternating current of 250 volts is dangerous to the life of any person through whose body such a current may pass. Also, that a continuous current of 700 volts is in like manner an unsafe amount of electrical force to be permitted to be used upon an imperfectly insulated wire.

But what is insulated? Mr. Edison says, "that the wearing out of the insulation is accounted for by the fact that the vibrations of the current cause corresponding vibrations of the insulating material and impairs its elasticity.†"

* November 30th, 1894. † *Engineer*, December 20th, 1889.

He would say, in conclusion, go on using electricity (as he himself was doing), but use it under safe conditions.

Mr. C. C. Leach said that at Seghill colliery the electric power plant only developed 32 per cent. of useful effect. He would like to know what was the useful effect of Messrs. Siemens' plant?

Mr. Siemens—73 per cent.

Mr. Leach said that the Seghill plant only yielded 32 per cent. on the water delivered compared with the indicated horse-power.

Mr. Siemens said that the useful effect of the plant would depend upon the efficiency of the pump. If the pump had an efficiency of 80 per cent., it would give 58 per cent. as the efficiency from the indicated horse-power. If Mr. Leach would give him full details he might be able to suggest an improved plant.

Mr. R. C. Jackson (Newcastle-upon-Tyne) said the only remark that he had to make upon this very valuable paper was in connexion with the steam efficiency of the plant as determined at Messrs. Siemens' works. This was obtained by high-speed engines of the Willans and Belliss types coupled direct to continuous-current dynamos. It was a difficult matter to ascertain the steam efficiency either per indicated horse-power or per Board of Trade unit, and the Newcastle Electrical Supply Company had been at considerable expense and trouble to carry out a series of steam-consumption trials in connexion with their plant, which consisted of slow-speed horizontal engines, with rope driving, and alternating dynamos. He thought it would be admitted that alternating dynamos for similar outputs would have an efficiency of 4 per cent. less than continuous current machines of similar output. Again, there was an allowance to be made for the loss due to the rope driving. They had endeavoured to ascertain the amount of that loss, and he was inclined to reckon it at from $3\frac{1}{2}$ to 5 per cent. for an engine of 200 to 300 horse-power of good class. Taking a plant under these conditions he found in practical working, for engines working from $\frac{3}{4}$ to full load, that they could produce a Board of Trade unit with 32 to 33 pounds of steam, and this result, he thought, would compare very favourably with those obtained with high-speed engines. Of course high-speed engines cost less in the first place, but against that they had Mr. Siemens' own dictum as to having a sufficient margin in hand. If anything went wrong with a high-speed engine there was no time to attend to it; either they could run or they could not. On the other hand, slow-speed machines of the Corliss type always gave some indication to the engineman, and there was generally time to have the matter attended to. With a high-speed plant it was obvious

that it would be essential to have a larger proportion of spare plant available, and that would to a certain extent increase the first cost and area of floor space covered.

Mr. A. L. STEAVENSON agreed with Mr. Jackson's preference of a slow-speed Corliss engine to any of the high-speed engines he referred to, as permanent solid work was much more likely to be got from them.

Mr. C. W. HUTCHINSON (Newcastle-upon-Tyne) said that it would be valuable to know the result of Mr. Siemens' experiments as to the efficiency of machines of various sizes. It would also be of interest to know what was the best manner of reducing the speed of the motor, and likewise the actual speeds employed. One great factor of the subject of electric power-transmission was that intermittent work would be found to give the greatest economic results, greater at any rate than constant work.

Prof. STROUD (Durham College of Science) said that from a scientific standpoint there were several points for consideration in connexion with the subject of electric transmission of power; such, for example, as the distribution of power in isolated parts of works by means of fixed electric cables. The power required was proportional to the current being used or to the work being done, whereas in the case of mechanical systems some power must always be wasted in driving shafting, etc., even when only a few of the tools are in use. He endorsed Mr. Steavenson's remarks as to the care to be taken in connexion with electric power-plants; and, in connexion with mining installations, it was especially necessary that great care should be exercised.

Mr. L. NEWITT (Newcastle-upon-Tyne) said that according to the paper the transmission of power over short distances now resolved itself into a comparison of electrical methods against shafting, belting, and steam pipes. Mr. Siemens said that "electric transmission of power is certainly more economical than the employment either of separate steam engines or transmission by belts or ropes.* On making a rough estimate of the efficiency of the electrical system as compared with shafting and belting, the following results were obtained:—In an electric plant for power-transmission, one might estimate the loss in the dynamo at 10 per cent., in the motor at 10 per cent., and in the cables at 5 per cent., a total of say 25 per cent. These figures must be almost correct, seeing that Mr. Siemens had estimated the loss at 27 per cent. In transmission of power by shafting, properly laid out and kept in good order, the losses due to friction would average from 6 to 10 per cent. This might seem very low, but from data which had been obtained at various

* *Trans. Fed. Inst.*, vol. viii., page 257.

times it seemed very near the mark. As an example of easy working, a line of shafting, 300 feet long, and 3 inches in diameter was set up, and when tested it was found that the whole length could be turned by two men exerting their weight upon a pulley 6 feet in diameter—that would be roughly 300 lbs. weight at a radius of 3 feet. Three similar lines of shafting had been tested with similar results. In the case of belt-transmission, it was found that tight belts were a great source of loss of power. If belts were, wherever possible, laid horizontally and somewhat slack, very little power was absorbed, probably not more than 6 per cent. The span over which belts work satisfactorily may, for the present case, be taken at 60 feet. It may be of interest to the members to know that in a large works on the Tyne, the average life of the main belts was about 18 or 20 years. Neglecting the losses due to friction in the main engine in each case, the losses due to shafting being 10 per cent., and adding the loss in belting of 6 per cent., the total loss in transmission of power over an area of 300 feet by 60 feet was 16 per cent.; whereas by electrical transmission there was a loss of 25 per cent. It appears therefore that in cases where the machinery was placed adjacent to the main engine he (Mr. Newitt) did not see how it was possible to have any system of transmission of power as efficient as that in use at the present time, viz., belting and shafting. The conditions, however, were entirely altered when it became necessary to run long lengths of steam-piping to separate engines. He (Mr. Newitt) thought that this was the great field for electric transmission, and that it should not be applied in ordinary compact works. In confirmation of this statement he would refer the members to the presidential address read by Mr. Richardson before the North-East Coast Institution of Engineers and Shipbuilders, from which it would be seen that the amount of leakage and condensation, which took place even in comparatively short lengths of steam piping, brought down the efficiency, in some cases, to as low a figure as 25 per cent.* The saving of coal pointed out in the paper led one to the conclusion that it was to a large extent due to the use of improved engines and boilers as well as to electric transmission. It would be interesting if Mr. Siemens could give some idea of the saving of coal due to the improved engines and boilers and also the saving due to the electrical transmission. In the earlier part of Mr. Siemens' paper the sizes of the electric motors were referred to, and their general efficiency was estimated at 90 per cent. This efficiency was probably true for large motors of 10 horse-power and

* *Trans.*, vol. xi., page 13.

upwards, but in several cases recently coming under his (Mr. Newitt's) own notice the efficiency of small motors, under 1 horse-power, had been less than 40 per cent. This defect in small electric motors appeared to be a bar to their individual application to small lathes or other machines, and he (Mr. Newitt) would be glad if Mr. Siemens would give some information upon this point.

Mr. R. LAVERICK asked whether some system of safety-plugs or cut-outs could not be adopted to prevent the possibility of too much current going through the motor and damaging or destroying it?

Mr. D. SELBY BIGGE (Newcastle-upon-Tyne) said that Mr. Siemens' paper would undoubtedly prove of the greatest interest, not only to the members of this Institute, but to all who were interested in the question of the electric transmission of power, and he must confess that to a great extent it supplied a link between the various papers that he had had the privilege of reading on the same subject, to which Mr. Siemens had alluded, and Mr. Richardson's most excellent presidential address. Mr. Siemens had confined himself largely to dealing with the question of the cost of production of electrical energy per Board of Trade unit and per electric horse-power, taking the case of Messrs. Siemens' works as an example, and had carried out a large number of experiments in order to arrive at that cost most accurately, but it appeared from the paper that this cost stopped, as it were, at the switch-board. He thought the information given by Mr. Siemens would have been still more interesting and valuable had he carried the matter a little farther, and given by experiments the exact coal-consumption per brake horse-power delivered by the motors; that is to say, the actual coal-consumption with all losses included throughout the entire canalization of mains, switching-gear, motors, speed-regulators, etc. Mr. Siemens valued the cost of a brake horse-power at 0·515d. per hour, but this was rather upon assumption. In his (Mr. Bigge's) opinion, the taking of the average working efficiency of all the motors at 90 per cent. was rather too high. He would ask Mr. Siemens if he could give any comparisons as to the total cost of production between, say, a large slow-running plant of 1,200 horse-power with triple-expansion engines, and of a plant of four smaller high-speed compound condensing engines of 300 horse-power each. Electric transmission of power must inevitably come to the front, both for long-distance transmission in mining and short-distance transmission in works, as the economical advantages to be derived from the system were plainly visible to all who examined and took an interest in these matters. During the last four years he had dealt with about

10,000 horse-power of electric motor work, and he had found that it was most important, as Mr. Siemens had pointed out, to have an ample margin of power in the motors.

Mr. D. B. Morison (Hartlepool) said that he was not a mining engineer, and was therefore not competent to estimate the probable economies to be effected in replacing steam by electric-power installations at collieries. But if collieries were worked at the same extravagant rate as the average shipyard and engine-works of this district, then he could say with certainty that the adoption of electric driving would be a commercial success. Mr. Siemens had given the members an extremely valuable and interesting paper, which contained the results of actual experiments most carefully made. Only those who had been personally engaged on experiments of this nature could appreciate the immense labour and expense in the preparation of such a contribution as that which Mr. Siemens had placed before the members of the Institute. He quite agreed with Mr. Siemens with regard to the imperative necessity of allowing a margin in the size and capacity of dynamos and motors for practical success, as nothing would retard the legitimate progress of electric driving so much as small, carelessly constructed, cheap, and unreliable installations. They might be sure that as electric driving became popular, competition would become keener, and there would be a tendency to produce cheap machines; but if those who adopted electric driving did not deal with experienced and reliable firms and accept their advice, they would find electricity a very doubtful blessing. The most interesting part of the experiments, from a commercial point of view, was the saving of 3,000 tons of coal per annum and the wages of six men, and there could be no doubt that when the transformation was complete there would be a farther economy of both coal and labour. He did not think Mr. Siemens could be aware of the almost universal extravagance in steam-driving in this district or he would not have allowed such an opportunity to pass without making a few comparisons. He had, however, said nothing, and therefore very considerately let them down far more gently than they deserved. He (Mr. Morison) lately had opportunities of testing steam-installations and of obtaining particulars of trustworthy tests, and the fact was indisputable that the consumption of steam of an average engine-works and shipyard was from 40 to 50 pounds per indicated horse-power, whilst there were not a few instances in ironworks of 80 to 100 pounds. In one case, where scattered steam engines in an open yard were replaced by electric motors equivalent to 35 horse-power, the change resulted in the saving of 30 tons of coal per week and the abolition of two steam-boilers with

their attendants. The consumption of steam in Messrs. Siemens' engines was about 22 pounds per indicated horse-power. This was accomplished by means of compound engines, and could be possibly reduced to 13 or 15 pounds with the highest class of triple-expansion engines. He had recently had the opportunity of inspecting an electrically driven works where an electric horse-power was produced for about 20 pounds of steam as against 25 pounds at Messrs. Siemens' works. Consequently the figures which had been put before the members were well within actual practice, and certainly were not extravagant or misleading assumptions. The question after all was a commercial one: it was a comparatively easy matter to ascertain the present cost of steam-power at any particular works, the economy which would result from the conversion to electric transmission, and the total cost of the transformation. He (Mr. Morison) said, however, that in such works as he had had an opportunity of examining, and allowing 15 per cent. for interest and depreciation, he was convinced that the capital outlay would be returned considerably within the period of ten years mentioned by Mr. Siemens. This economy, however, of course depended entirely upon existing conditions, and would vary according to circumstances. There were many compact works, of course, where high-pressure condensing steam-engines could be applied direct to the shafting, and in such cases the economy obtainable by electric driving would be confined to that gained by independent motors for cranes or heavy machines. It was not such works as these, however, where the great field of application was, but rather in yards and factories, where there were large numbers of scattered engines which were now working with an altogether unnecessary and extravagant consumption of steam and coal.

Mr. JOHN H. HOLMES (Newcastle-upon-Tyne) said that there seemed to have been some doubt thrown by some gentlemen upon the efficiencies obtained by electrical methods, and he would only like to corroborate the results which Mr. Siemens had submitted by quoting some tests made by Prof. Alex. B. W. Kennedy, on a set, the dynamo of which was constructed by his (Mr. Holmes') firm, tested at Messrs. Willans & Robinson's works near London. Although the plant was of considerably less power than that described in the paper it had an electric efficiency of 85·6 as against the 86 per cent. mentioned in the paper. The pounds of water used per indicated horse-power were 17·4 as compared with 19·5; and the pounds of steam per electric horse-power were 20·3 as against 22·7, and per Board of Trade unit 27·3 as against 30·45. The slight difference in favour of his plant may have been due to the fact that

the water used for working the air-pump was not taken into account. There was very little difference between these figures, and any person desiring to introduce electric transmission might confidently adopt them as fairly representing the average efficiencies that could be obtained by the makers of modern electric machinery.

Mr. CRAWFORD (London), referring to the diagrams (Figs. 6 and 7, Plate XV.) comparing the efficiencies of the two types of engines, said that water consumption was only one measure of the value of an engine, and while being fully aware of its influence on the total efficiency, he thought its importance had been exaggerated by non-practical engineers. The efficiency curves (Fig. 7) were interesting and more valuable than the other (Fig. 6), but it should be borne in mind that the efficiency shown in Fig. 7 was not the total efficiency. Such important factors as endurance and reliability had not been compared, because they could not be determined in so short a period as six months. In his opinion the simplicity, accessibility, and want of novelty in the Belliss engine were all in its favour, and the reasonable probability (from considerations of strength, pressure per unit of wearing surface and type), was that the double-acting engine would be the most enduring and reliable. His remarks might be taken to apply to the whole of Mr. Siemens' paper, and shortly, he meant to say that it was easy to excel in any one direction, but it was much more difficult to secure all-round excellence.

Sir B. C. BROWNE asked, in the case of a shipyard or engineering works adopting an electric plant, what was the smallest size of motor Mr. Siemens would advise them to adopt? If they had a number of machines of different sizes requiring different powers to drive them, what would be the standard size of motor, and how would he group the machines? With reference to mines, had the difficulty of working in a wet or damp atmosphere been entirely got rid of? Some comparisons had been given of the worst cases of steam-engines with the most efficient electric plant. This might be very interesting, but he thought it was not of the smallest conceivable practical use; they must compare steam at its best with electricity at its best.

Mr. SIEMENS said he thought it perfectly fair that he should say to the owners of shipyards and other works, "Your existing machines are wasteful; supplant them by electric transmission, so that you may obtain a great saving." If there was a new works to be established, it was right to compare the best practice of the steam engine with the best practice of electric power-transmission; but, with regard to existing works, he thought it quite right to point out that if wasteful steam-engines were

abolished electric power-transmission could be substituted with great advantage. With regard to new works, the advantages had been referred to by Mr. Selby Bigge when he described the investigation which was made with regard to the Small Arms Factory at Herstal, which he (Mr. Siemens) also described before the Birmingham Institute in March, 1893. The Belgian engineers made a careful and detailed investigation as to how they should transmit the power, whether by ropes, belts, scattered steam engines, or by electric transmission, and thus the best practice of steam was compared with the best practice of electric power-transmission to the advantage of the latter. He was careful to say at the conclusion of his paper that "generally speaking, electric transmission is most applicable where power is wanted at a number of places scattered over the works, and especially in and about mines and collieries." If they wanted to investigate whether they should use electric power-transmission or not, they must make the comparison with what they had got. He ventured to say to Mr. Holmes that he should not compare a special trial at Messrs. Willans & Robinson's works, where everything was done to make the efficiency as great as possible, with these tests which were brought before the members as the results of actual working conditions, and which could be reproduced at any colliery or shipyard with certainty. Mr. Parsons asked why a particular form of condenser was used. The reason was simply because they happened to have them, and they gave a vacuum of 26 inches. Mr. Wood had asked for an explanation of the automatic adjustment of motors to their load. To answer this question, however, would take him too long, and he must refer him to the paper which he had read before the Society of Arts.* With reference to the life of electric plant, there was really nothing to wear out except the motor, and he had already pointed out that this should be made amply large for its work. In regard to the danger of shocks, Mr. Steavenson surely had not taken into consideration that all conductors should be insulated, and in his paper he was, of course, speaking of first-class work, properly done, by people who understood their business, and one of the principal conditions was that they could not get a shock anywhere. Therefore the question of danger he thought did not enter into the case. The way in which power was to be transmitted to the machines and the smallest motors to be recommended were points raised by more than one speaker. This depended entirely upon circumstances. They had ¼ horse-power motors coupled direct to fans, which naturally could not be driven from shafts. They had another small motor coupled direct to an emery-wheel for sharpening

* *Journal of the Society of Arts*, vol. xxxi., page 531.

tools, etc., and a number of motors ranging from 4 to 40 horse-power, driving groups of machines, shafting, and so forth. The power of the motor to be employed was therefore simply a matter for consideration in each case. If they had a number of lathes, and each one was only used occasionally, they could, of course, put one to each lathe, but it would be extravagant. The same sized motor could be put to a shaft to drive the six lathes, and it would have sufficient power to drive each lathe when wanted, but of course it might not be sufficient to drive all six together. Mr. Jackson had referred to steam efficiency, and was rather of opinion that his way of rope-driving was nearly as efficient as direct driving; but he (Mr. Siemens) might remind them of Mr. Crawford's remark that all the circumstances should be taken into account. In visiting such a station as that of the Newcastle Company, they would be struck with the great waste of space. Direct-driving machinery of four times the power could have been put into the same space. Space might be cheap, and therefore it was not so necessary to save it, but it was sometimes a material consideration in deciding upon the kind of plant to be adopted. He would certainly always be against either belt or rope-driving for electric installations, because it introduced another link which might go wrong, and it was also a factor of cost. With regard to the efficiency of the various sizes of motors, very small ones under 1 horse-power gave from 50 to 60 per cent., 2 horse-power motors from 79 to 84 per cent., and the larger ones up to 94 per cent. The methods of reducing speeds were, as already indicated, very various. In the case of fans and emery-wheels the motor was applied direct to the axle, without reduction; in other cases by means of shafting; and in others by wheels and pinions, etc. This was also a matter for consideration in each particular case. Mr. Newitt thought the loss in shafting was not very great. He had really answered this point, because naturally if the work was grouped round the steam-engine there was no necessity for electric transmission. It was in cases where there was a certain distance to the farthest point at which power was required that the advantages of electricity were apparent. With regard to the life of the cables, he might remark that they were covered with lead, and some perfectly good lead pipes had been discovered recently which were used in Pompeii, so that he might estimate the life of lead-covered cables not at 18 but at 1,800 years. In reply to Mr. Laverick, they could put in cut-outs to prevent overloading, but they were a terrible nuisance, because they frequently acted when they were not wanted, hence they were generally left out. Mr. Selby Bigge had considered that the information stopped short at the

switch-board; but he (Mr. Siemens) thought he had said quite plainly that the loss in leads at their works was 5 per cent., and the average efficiency of the motors might be taken at 90 per cent. This was not a fancy figure, but represented actual facts. All the figures in the paper were based on very careful observations, and were absolutely reliable. He was obliged to Mr. Morison for having generally endorsed the statements made in the paper, and he hoped that everybody would take his remarks to heart.

Mr. T. RICHARDSON (Hartlepool) wrote that he had read with great interest Mr. Siemens' paper on "Electric Transmission of Power," which would prove of great value and assistance to those who were considering the advisability of introducing electric driving into works. It added to the data which they already possessed, and the remarks and advice of one possessing so much experience must have great weight, and give encouragement to any who were thinking of moving in this direction. It was a move, however, requiring very careful consideration; for whilst it was doubtless one which might be made with every confidence in the case of works where the machinery—being spread over a large area—was dependent on a number of scattered engines for power, it might in the case of small and compact works, where it was not necessary to carry steam any distance, prove to be of little, if any, advantage. In these days, when there are so many opportunities in old-established works for economizing by the introduction of modern tools, any expenditure should be directed into the channel most likely to result in the greatest commercial success, and it was quite possible that a large expenditure might be more advantageously undertaken for new tools rather than for an electric-power plant. They knew that in the case of mines, valuable and economical assistance had been obtained by the use of electrically driven pumps and drills, often where it would have been impossible to utilize steam. Where the work required to be done was situated in workings a considerable distance from the shafts and required immediate treatment, the difference between the time occupied in applying electric motive power as against steam power had often been of considerable gain. In the case of ironstone-mines, where there was an outflow of water from the workings, by adopting a system of storage, it could be utilized for driving a dynamo, and very great economy might be obtained by the adoption of electric driving. The saving of coal in such cases would be large—for the majority of ironstone-mines are situated a considerable distance from the source of their coal-supply. In addition there would be other savings contingent on the application of electric power, which

have been referred to in papers and discussions on the subject. So that, whilst the application of electric driving in mines, etc., has been proved to be capable of adoption with great benefit, in large engine-works much has yet to be developed, and such results as Mr. Siemens had obtained in machine-works are of great value to those who are enquiring into this question. The works with which he (Mr. Richardson) was connected had for some time been carefully looking into this question, and extensive experiments had been made, some of which were recently laid before the members of the North-East Coast Institution of Engineers and Shipbuilders.* Arrangements were gradually being made which would eventually result in steam power being replaced by electric power in the works with which he (Mr. Richardson) was connected.

The PRESIDENT said that he, as he had pointed out in his address, felt the great importance of electric transmission, and he thought that, if they could be satisfied as to the cost of electric transmission compared with other methods, it would be speedily introduced to a greater extent. He then proposed that the hearty thanks of the members be accorded to Mr. Siemens for his paper. Many of the members had recently had an opportunity of passing through the works of the author's firm, and they were now farther indebted to Mr. Siemens for his valuable and interesting paper.

Mr. W. C. BLACKETT seconded the proposal. He was sure that they had all listened with great profit to themselves to that excellent paper, although, as one who had to obtain his livelihood from the coal-trade, he was personally somewhat dismayed by the enormous saving of coal which was to be effected. He hoped, however, that this saving would not take place at once, and that they would have ample time to put their houses in order.

The vote of thanks was carried with acclamation.

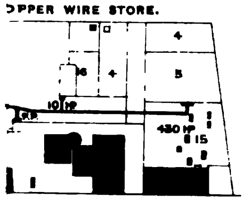
The following paper, by Mr. J. Henderson, on "Magnetic Declination in Mines," was taken as read :—

* *Trans.* vol. xi., page 13.

REFERENCE NOS.

FIG. 1.

- ACKING ROOM AND TINSMITH'S SHOP.
- ABLE TESTING ROOMS.
- ABLE TANKS.
- ABORATORIES.
- ALIBRATING SHOP.
- REMAN'S LODGE.
- MPS AND SWITCHES, WITH PATTERN SHOP ABOVE.
- ACKING CASE AND JOINERS' SHOPS.
- ORE TESTING AND INSTRUMENT ADJUSTING ROOMS.
- OTTON COVERING, ABOVE CORE TANKS.
- ORE TANKS.
- ORE TANKS, GUTTA PERCHA SHOPS OVER.
- OPPER WIRE STORE.



12. CENTRAL ELECTRIC GENERATING STATION
12A. BOILERS.
13. CONDENSER ROOM.
11, 12, 13 (UPPER FLOOR) GUTTA PERCHA CORE COVERING.
14. HYDRAULIC TESTING SHOP.
15. DYNAMO TESTING SHOP.
16. CHEMICAL DEPARTMENT.
17. ELECTRIC CRANES.
18. STEAM CRANES.
19. WEIGH-BRIDGES.
20. LIFTS.
21. DYNAMO SHOPS.
22. STORES.
23. GUTTA PERCHA SHOPS, WITH STRANDING SHOP ABOVE.
24. INDIA RUBBER DEPARTMENT.
25. WIRE WINDING SHOP.
26. CARBON DEPARTMENT.
27. INSTRUMENT DEPARTMENT.
28. INSULATOR, OVERHEAD LINE & BATTERY DEPARTMENT.
29. SUBMARINE CABLE SHOP.
29A. YARN WINDING SHEDS.
29B. YARN STORES.
30. MILLWRIGHTS' SHOPS.
31. TIME OFFICE.
32. GENERAL OFFICES.

CENTRAL STATION.

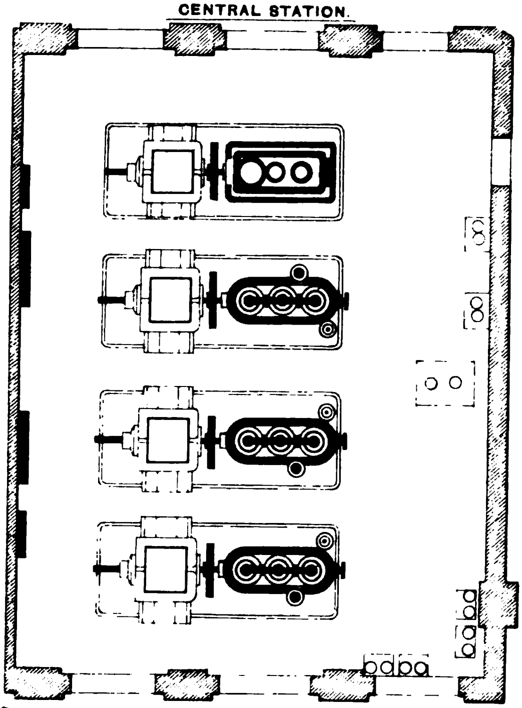


FIG. 2.

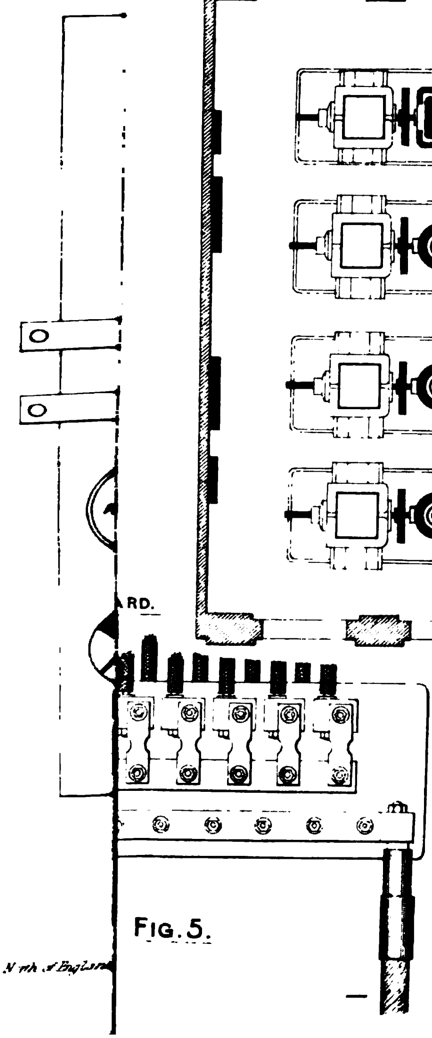


FIG. 5.

N rth of England

MAGNETIC DECLINATION IN MINES.

By JAMES HENDERSON.

Considerable attention having recently been given by mining engineers and surveyors to the effect of magnetic attraction on the needle of the miner's dial or compass, a few remarks on the subject, chiefly in connexion with the mining district of St. Just in Cornwall, where great local attraction generally prevails, may prove interesting.

The district in question is situated near the western extremity of Cornwall, about 3 miles north of Lands End, and abutting on the precipitous northern coast. It consists chiefly of granite, bounded towards the sea by a comparatively narrow band of hornblende-rock and felspathic "killas" or slate. The line of junction with the granite is irregular, and on either side of it, the mines of the district, now, however, sadly reduced in number, are chiefly situated.

The few mines still at work produce a fair quantity of tin, notably the Levant mine and the celebrated Botallack mine, formerly rich in copper ore, which was raised in the belt of killas already referred to, but whose operations are now confined to the Wheal Cock portion of the sett, which is now being worked for tin.

Adjoining the Botallack mine to the south is Wheal Owles, rendered notorious by the irruption, on January 10th, 1893, of water from an abandoned portion of the workings, and the consequent loss of 20 miners, who were overwhelmed, and whose bodies still remain unrecovered.

The two latter mines, Botallack and Wheal Owles, are selected from the St. Just group for reference, as respectively exemplifying the effect of local attraction and the perennial variation of the magnetic declination.

The Botallack Mine.

In the now abandoned Crown portion of this mine, which extends for a long distance beneath the bed of the Atlantic Ocean, a great amount of local magnetic attraction prevails, rendering compass-bearings quite unreliable.

In order to obtain a correct map of the workings, it was necessary to connect the courses of the different levels with those taken in the long and tortuous diagonal shaft, which was sunk on the underlie from the surface to the bottom of the mine.

The attraction referred to appears to be caused by veins of magnetic iron-ore pervading the mass of felspathic slate, and concentrating in the copper-ore lode and branches on which this part of the mine was worked. From the rapid coating of ferruginous matter over the exposed surface of the levels, it was almost impossible for the surveyor in his periodical visits to detect the minute strings of magnetic ore which might have been affecting the compass-needle, and he had, consequently, to exercise his ingenuity so as to avoid dependence on his bearings for correct results.

In scarcely any mine in the county of Cornwall, except in the instance already given of the Crown portion of the Botallack mine, is there a shaft of sufficient dimensions to allow of a draft-line taken with a theodolite at the surface being transferred to the workings below, as is the case in collieries generally, and therefore recourse must be had to the miner's dial or miner's theodolite, and the polarity of the underground survey must be established by the compass-bearing of at least one of the lines of the intended traverse.

Where no local attraction exists the miner's dial is well adapted to the purpose intended, and as the needle can be thrown off when considered advisable the traverse can be continued on the theodolite principle. But in cases such as at Wheal Cock, in the Botallack mine, where great magnetic attraction prevails, the surveyor has to go, perhaps, nearly ½ mile away, possibly in a cross-cut, into the solid granite in order to ensure a true bearing.

It is a well-known fact that in parts of the Botallack mine the needle has been deflected to the extent of 50 or even 60 degrees from its proper direction, and the utmost care has to be used by the surveyor in consequence.

Thus, in a recent underground survey at Wheal Cock, the surveyor was obliged to seek for a true bearing at a distance of ¼ mile from the shaft, and using a draft-line at that place of only 16 feet in length as his base, he carried on the whole of his subsequent survey by means of an angular instrument of recent invention, without reference to any further needle reading. The work involved no less than 363 draft measurements, and occupied seven days in its accomplishment.

Fortunately the shaft at this part was on the underlie from the 160 fathoms level (where the base-line referred to was adopted) downwards, and consequently the traverse was continued from level to level, to the bottom at the 210 fathoms level, without once breaking the connexion established with the starting-point.

Wheal Owles.

The sad catastrophe alluded to in the introductory remarks of this paper, although, no doubt, attributable to the incorrect application of the miner's dial, was found, on investigation, to be due not to the neglect of the surveyor in dealing with local magnetic attraction, which appears in this mine to have been but slight as compared with the Botallack mine, but to ignorance of the perennial variation of the needle which at this part of the county is about 7 minutes easterly per annum.

In the plan of the underground workings, periodically kept up to date with care, the same magnetic meridian was used for a period of forty years.

Thus, the levels of some old workings of great extent and full of water were unfortunately holed by the miners working in a new part, where, by the plan, a safe barrier of solid ground was shown to exist between the old and new portions of the mine.

A very simple method of ascertaining the variation of the compass from the true north line is to take the bearing by compass from any point to any distant object shown on a sheet of an Ordnance map, both ends of this imaginary line being recognizable thereon; then, as these sheets are all drawn with their borders representing true north-and-south and east-and-west lines, the bearing of the line in question can be compared with that given by the compass, and their difference will be the variation from the true meridian and sufficiently accurate for ordinary mine-surveying.

The surveyor who uses the miner's theodolite should bear in mind that his tripod-stands, which in a traverse should be three in number, must be perfectly rigid and free from torsion. If they are not to be depended on in this respect he must adopt the system of reading the compass-bearing of each back and forward observation, for however much such readings may be affected by local attraction the error for the back observation is the same, of course, as for the forward one, and hence the resultant angle (the forward bearing minus the back bearing) is correct.

The use of the compass-needle has in too many cases been condemned. Its misuse, however, is generally the real cause of error. When properly managed it is an instrument of vast importance, and under existing circumstances is, indeed, of actual necessity to surveyors of metalliferous mines.

The following paper, by Mr. R. Russell, on "The Extension of the West Cumberland Coal-field Southward and Northward under the St. Bees Sandstone," was read at the General Meeting, held in Whitehaven on June 21st, 1894* :—

* *Trans.*, vol. vii., page 638.

THE EXTENSION OF THE WEST CUMBERLAND COAL-FIELD SOUTHWARD AND NORTHWARD UNDER THE ST. BEES SANDSTONE.

BY R. RUSSELL, C.E., F.G.S.

The exposed portion of the West Cumberland coal-field extends from Barrowmouth along the coast through Whitehaven, Harrington, Workington, and Flimby to Maryport, whence it takes a north-easterly course to Bolton Low Houses. With the exception of a small area between Micklam Point and Salter Beck, where the Lower Coal-measures are brought up to the surface, the whole series of coals are generally present. These coal-seams are well known, and have been largely worked at Whitehaven, Harrington, Workington, St. Helens; Seaton, Clifton, and Camerton in the valley of the river Derwent; Flimby, Ewenrigg, and Ellenborough near Maryport, Dearham, Crosby, Aspatria, and Bolton.

Forming the eastern boundary of the Carboniferous rocks, the limestone extends from Egremont along the west side of the Ehen valley to Yeathouse. Thrown down to the north-east by the Yeathouse fault, it runs through by Stockhow Hall, Kirkland, and Lamplugh to Ullock, thence by Pardshaw and Eaglesfield Crags; crossing the river Derwent between Brigham and Papcastle, it takes a north-easterly course on the north side of the Derwent valley, through Redmain, Blindcrake, and Sunderland Heads to Bothel; thence eastwards by Ireby and Uldale to Caldbeck, whence it ranges south-east through Haltcliffe and Hutton Roof to Greystoke Park.

South of Whitehaven, the Coal-measures are overlain by the Permian rocks forming part of the St. Bees Sandstone series. At Barrowmouth, they are seen resting unconformably on the Whitehaven Sandstone. From the coast, they run up along the side of the cliff and over the ridge at Croft pit, cross the road from Whitehaven to St. Bees at the foot of the Demesne Brow, coming down into the St. Bees valley south of Stanley Pond, and up through Linethwaite wood to the Egremont road. From this point the boundary between the Permian and the Carboniferous rocks is partly a natural and partly a faulted one as far as

Egremont, and probably as far as Grange and Kirk Beck. Thence it passes over Cold Fell, across the river Calder near Prior Scales, along the west side of Ponsonby Fell, into the valley of the river Bleng. Following the south side of this valley, it crosses the river Irt near Irton Hall, winds round into the Mite valley, near Muncaster Mill, and along the base of the fell nearly to Ravenglass. A narrow strip of the Permians extends along the coast south from Ravenglass through Eskmeals, Bootle, and Silecroft to Haverigg Point.

On the north of the Cumberland coal-field, the St. Bees Sandstone is faulted down against the Coal-measures along a very regular line from Maryport, through Crosby, Aspatria, and Brayton, to Bolton Low Houses. Eastwards, as far as the river Caldew, the line is more irregular. Here the Penrith Sandstone first begins to put in an appearance if approached from the west, or disappears if this rock has been followed from the east side of the county.

South of St. Bees, superficial deposits of various kinds cover up the solid rock, but there can be no doubt that the St. Bees Sandstone exists uniformly over the low-lying country along the coast. The height of this tract of country above the sea-level rarely exceeds 200 feet, but there are places where it attains a much higher elevation. Thus at St. Bees Head, the height is 466 feet, at Winscales 440 feet, at Cold Fell 950 feet, near Prior Scales 643 feet, at Ponsonby Fell 731 feet, and at Bleng Fell 800 feet above the sea-level.

In the country north of the Aspatria fault, the Red Sandstone, in one instance only, reaches a height of 400 feet above the sea-level; it rarely exceeds 300 feet, and is more generally about 200 feet above the level of the sea. Viewed from the heights at Moota Hill or Brocklebank Fell, the country stretching away to the Solway Firth appears to be very flat. In reality it consists of a series of undulating ridges and mounds. This particular surface-configuration is due entirely to the deposits of sand, gravel, and boulder clay which cover and obscure the solid rocks on which they rest. Owing to this superficial covering, the solid rocks seldom form any physical features, and the strata are only exposed in the sides and channels of the stream-courses.

It is evident that the red rocks, if they did not originally cover the whole of the exposed coal-field, at any rate covered a very considerable portion of it. In various instances, isolated patches of these rocks, which have been thrown down by faults, are preserved in the form of faulted inliers, enclosed on all sides by faults, or partly by faults and partly by natural boundaries. Thus, St. Bees Sandstone occurs at Ingwell, at

Rheda and Birks near Frizington, and at Yeathouse; the breccia appears at Keekle, extends from Walkmill to Weddicar Hall, from Millyeat to Frizington, from Yeathouse over the ridge to Arlecdon Moor and Arlecdon Hill, it occurs between the faults at Winder Mines, Parkside Mining Company, on Whillimoor, at Blenket Rigg and south of Dean Moor, and at Gilgarron, near which place a small patch of breccia, composed entirely of large blocks of limestone, lies between two faults.

The Permian rocks, it has been observed, lie upon Coal-measures at Barrowmouth, limestone near Egremont, Lower Silurian slate east of the river Ehen, and finally pass on to the Borrowdale series, extending from Kirk Beck to Muncaster Fell, showing a well-marked unconformity between them and the older formations. Now, it is quite evident that the occurrence of any of the divisions of the St. Bees series is no evidence as to the existence of coal-bearing measures below it, for we have seen that it rests in this locality on rocks ranging from the Upper Coal-measures to the Lower Silurian. In order, therefore, to form an opinion as to the extension southwards of the Whitehaven coal-field under the Permians, we must draw our conclusions from data of quite another character. That the Coal-measures do so extend is a well-known and ascertained fact, but to what distance southwards the coal-field does extend, and whether the coal-seams run out to sea or turn inland, are questions which admit of some speculation.

The workings from the old shafts in the vicinity of Preston Hows were carried under the St. Bees Sandstone. From the Croft pit, the coal has been worked for some distance in the direction of Sandwith, and the base of the red rock proved by boring upward from the underground workings.

Again, at Beckfoot, near St. Bees, Carboniferous rocks have been proved at the depth of 1,125 feet. At Orgill, near Egremont, almost due east of St. Bees, limestone was found under the breccia at the depth of 824 feet; in the valley south of Egremont, at the depth of 569 feet; and near Wotobank, at the depth of 1,138 feet. This is the most southerly place at which the nature and character of the strata under the St. Bees Sandstone has been ascertained. Bore-holes have been put down near Braystones and Drigg Cross, but they were not carried to a sufficient depth to prove the thickness of the red rocks.

The foregoing remarks state generally all that is known at the present time in reference to the thickness of the Permians and the classification of the rocks on which they rest in the district between Barrowmouth and Ravenglass. It may therefore be inferred that Carboniferous rocks are

now ascertained to lie under the Permians as far south as Beckermet, but between Beckermet and Ravenglass the ground is altogether unproved.

Near Whicham, the limestone comes to the surface, and the same rock is proved below the Red Sandstone at Haverigg Point. The appearance of the limestone near Whicham, and the knowledge that it underlies the Red Sandstone between Whicham and Haverigg, prove the continuation of the Carboniferous rocks along the coast-line south of Ravenglass. It may therefore reasonably be surmised that in the district between St. Bees and Ravenglass they likewise follow the trend of the general strike of the Carboniferous rocks on the north, and extend under the Red Sandstone nearly as far as the river Esk. Here they are probably thrown westwards, the Eskdale granite running down as far as Hall Waberthwaite.

The inclination of the coal-seams at Whitehaven is towards the west and south of west, and the direction of the dip of the limestone in the neighbourhood of Cleator and Egremont has a similar bearing. Too much dependence, however, cannot be placed on this fact alone when two places several miles apart are to be compared, especially when the information in regard to the district between Egremont and Ravenglass is so meagre as it is at present. But the westerly and south-westerly dip of the Carboniferous rocks generally, and the knowledge that they extend along the base of the Fell district from Egremont north to Cockermouth, and from Cockermouth north-east to Caldbeck, points to the probability of the Carboniferous strata winding round under the St. Bees Sandstone in the district between Egremont and Ravenglass.

Taking the south-westerly direction of the dip as continuous throughout this comparatively unknown district to the south of Egremont, and ignoring faults, which doubtless exist, but of which nothing is known, the strike of the measures would range somewhat in the direction of the thick broken line shown on the map and approximately paralleled to the coast-line (Plate XVI.).

The section (Fig. 3, Plate XVII.) which runs south-east from St. Bees to Muncaster, shows the probable occurrence of the Coal-measures under the Permians between St. Bees, where they have been proved, and the unknown district to the south. Variations in the direction and amount of the inclination of the strata, and the results of faults might have the effect of throwing out the coal-seams altogether, but the changes produced by these causes might have an opposite effect and throw the Coal-measures farther inland, just as the Red Sandstone runs eastward from the coast to Ponsonby Fell. On this section, these two circumstances are supposed in some degree to counteract each other,

and the general run of the coal-seams would consequently be represented by a continuous line, although there would in reality be local changes which could only be ascertained by actual proof. On the plan (Plate XVI.) the probable outcrop of the main band coal-seam is shown by the broken line, and the extreme limit of the Coal-measures by the thick broken line. The probable depth to the Coal-measures would be 1,300 to 1,400 feet.

The Aspatria fault, which runs from Maryport through Aspatria to Bolton Low Houses, brings in the St. Bees Sandstone against the Coal-measures. Its position at the surface can generally be approximately determined. It is hardly likely that there is one great dislocation, but rather a series of downcast faults, the combined effect of which has not yet been actually proved. At Maryport, at Crosby, at Aspatria, and at Bolton Low Houses a fault has been proved, which is evidently the first of the series of downthrows which ultimately bring in the full thickness of the St. Bees Sandstone.

Generally speaking, the inclination of the strata in the Maryport and Aspatria portions of the coal-field is parallel to the direction of the fault, but there are exceptions. At Birkby and Dearham the dip is westerly, but at Crosby it is south-easterly, increasing rapidly northwards. At Brayton it is westerly again, but at Bolton Low Houses, in the space between the Aspatria and Parsonbridge faults, the inclination is towards the north-west.

A dip drift has been driven from No. 1 pit, Crosby colliery, for a distance of about 2,150 feet. In this drift the measures are seen to rise gently to the north-west for 955 feet, and then the inclination increases rapidly northwards to 80 degs. Owing to this north-westerly rise of the strata, the drift cuts through the Lower Coal-measures and finally reaches the top of the limestone, probably on the upcast side of the fault.

The results of the Crosby explorations, and the unusual direction of the inclination of the strata there, are apparently unfavourable to the continuation of the coal-seams under the Red Sandstone on the north side of the fault. Farther, the general westerly dip of the beds is not very encouraging, as the continued existence of the Coal-measures north of the Aspatria fault, unless the direction of the dip changes, would depend on their repetition by faults, as is the case in the exposed coal-field. The bore-holes at Maryport and Allerby are unsatisfactory. They were situated too near to the fault to give results of much value. However, notwithstanding the adverse circumstance above-named, the Brayton main coal has been proved under the St. Bees Sandstone at the new pit

near Brayton station, on the down-cast side of the fault, and about a mile on the north side of the fault. The workings from the new winning will furnish a general notion as to whether any change has taken place in the direction of the inclination or not.

The strata in the district between the Aspatria fault and Bowness occupy a basin. At West Newton and Shalk, the St. Bees Sandstone occurs at the surface, and the same rock has been proved under the surface-drift at Bowness. This basin-shaped area is likely to be traversed by faults, notably the continuation south-westward of the Cummersdale faults, and the extension northward of the Westward Cottage and Parsonbridge faults. The central portion of the district is occupied by Lower Lias, Keuper marls, and Bunter sandstone. From Great Orton on the south to Kirkhampton on the north, and from Aikton on the west to the river Eden on the east, the Lower Lias occurs in the centre of the basin. North of Carlisle, the Keuper marls overlying the Kirklinton sandstone are very thin. At Lyneside, the marls are not present, but under 36 feet of sand and clay the Kirklinton sandstone was found, and the St. Bees Sandstone at a depth of 95 feet, proving the continuation of the syncline in a north-westerly direction.

On the south-west of the river Eden, the Lower Lias is most probably thrown down against the marls. because in the district about Abbey Town the marls are proved to be much thicker than they are at Carlisle. At Kelsick Moss under clay, sand, and gravel 198 feet 6 inches thick, 945 feet of Keuper marls were proved. Under the marls was a grey sandstone resembling the grey sandstone in the river Eden near Cargo, and below the grey sandstone a soft red sandstone, but whether Kirklinton or St. Bees Sandstone it was difficult to determine from the samples.

Practically, within the whole of the basin from the Aspatria fault to the Solway Firth the character of the rocks underlying the St. Bees Sandstone is almost unknown, except that coal has been proved under it at Brayton. After giving due consideration to the adverse circumstances of the general inclination of the known coal-field, and the particularly unfavourable nature of the exploring drift at Crosby colliery, it is difficult to conceive of the entire removal of the Coal-measures from this syncline before the deposition of the St. Bees Sandstone. It is more natural to conclude that within the syncline between Wigton and Bowness the coal-bearing strata were not denuded prior to the time when the St. Bees Sandstone began to be formed, and that a coal-field of greater or less extent was left in this district and covered over by the newer formations, and thus preserved from all farther denudation. In the area between the extension

northwards of the Parsonbridge fault and the river Eden, the Carboniferous rocks will lie at a great depth, because in this locality the full thickness of the Keuper marls and of the St. Bees Sandstone will have to be passed through before they are reached, but at Carlisle the thickness of the overlying rocks will probably not exceed 1,500 or 1,600 feet, and along the coast north of Allonby their thickness may not be more than 1,300 or 1,400 feet.

Reviewing the whole of the evidence which at present exists, the probability is, that the Cumberland coal-field of the future will extend from Whitehaven southwards to Drigg, with a breadth inland, south of St. Bees, of from 1 to 1½ miles, and seaward to an unknown distance, probably several miles. With reference to the probable northern extension of the coal-field between Maryport and Waverton on the south and Skinburness on the north, it will possibly lie at a moderate depth, and extend westwards for some distance under the Solway Firth. Within the faulted basin between Abbey Town and Kirk Andrews-upon-Eden the seams will lie at the greatest depth, perhaps not less than 2,400 feet. At and north-eastwards from Carlisle, the Carboniferous rocks, as already stated, may be reached at from 1,500 to 1,600 feet, but whether these rocks in the neighbourhood of Carlisle will contain workable coal-seams or not, yet remains for the boring-machine to prove.

Mr. W. FLETCHER (Carlisle) asked if the author was of opinion that the New Brayton pit was on the north side of the Crosby fault?

Mr. RUSSELL said he understood that to be so.

Mr. W. FLETCHER said he was reluctant to differ from so high an authority, but his own opinion was that the fault on the north side of which that pit was situated was a trifling branch from the main fault which ran up the valley of the Ehen, and had been proved at No. 3 pit, Brayton colliery. He thought that the Crosby fault would be found on the north-west side of the New Brayton pit.

Mr. R. P. W. OSWALD (H.M. Inspector of Mines, Whitehaven) thought the No. 4 pit, Brayton colliery, was on the upcast side of the fault, and that they had not yet proved the main fault.

Mr. J. D. KENDALL (Whitehaven) said that he had nothing to add to what he said in 1883, when he read his paper "On the Structure of the Cumberland Coal-field" *—at all events not with regard to that portion north of Maryport; there was still a good deal to be done by either the sinker or borer in that area before any definite opinion could be formed.

* *Trans. N. E. Inst.*, vol. xxxii., page 319.

From a geological point of view it was a mere matter of speculation. The same remark applied to the area south of Egremont, but he might point out one or two facts, which he thought were not noticed in the paper, with reference to the band of Carboniferous Limestone between Rowrah and Bigrigg. The trend of that rock was to the south-west, which was pretty much the trend of the Coal-measures too. Now, the distance between Rowrah and Bigrigg was 5 miles, and the net aggregate throw of the faults up west was 5,700 feet between these points. It was stated in the paper that the probabilities were that the coal-field would be found extending inland about 1½ miles from St. Bees. Now, at Bigrigg, which is only 2 miles from St. Bees, they had the top of the limestone at the surface; and bearing in mind the number of faults crossing that band of limestone, and which are all up to the west, between Rowrah and Bigrigg, he thought it extremely likely that they had not yet found the last of those faults, and that there were others hidden underneath the Red Sandstone. He thought it extremely likely that if these faults were repeated under the Red Sandstone, they would find the Coal-measures much farther seaward than Mr. Russell expected. Again there was a large east-and-west fault passing through the Cleator Moor coal-field near to Mr. Stirling's No. 4 pit, and a continuation of that fault would strike the coast a little south of St. Bees Head. Now, the throw of that fault was about 1,200 feet up to the south, and he thought it was very likely that the fault would continue to the coast, and have a very serious effect on the southern continuation of the coal-field.

Mr. R. W. MOORE said, as regards the coal-field south of St. Bees Head, in 1890, when it was said that coal had been discovered at Bootle, he ascertained that the report was due to some pieces of coal and shale having been found in some shallow holes that had been dug on an estate, called Hyce Moor Side, north-west of Bootle railway-station. The owner of that estate also told him that in cutting a drain he cut a spring some six years previously, and after the water had drained off a lot of small coal had come away. These were the slender bases upon which the report was formed, and it still remained for a deep bore-hole to be put down to show that the coal-field extended so far southward. He agreed with Mr. Oswald that the main fault had not yet been reached on the north at Brayton colliery.

Mr. WATKYN THOMAS (Cockermouth) asked what was Mr. Russell's explanation of the fact that, if—as he understood him to assume—the Brayton seam in the new pit was on the north or downthrow side of the fault, there was no difference in depth between the No. 3 pit (on the

south side) and No. 4 pit (on the north side), as the two seams were practically on the same level? If the fault that crossed that district was supposed to be a big fault, these facts seemed at once to prove that the No. 4 pit was on the upthrow and not on the downthrow side of the fault.

Mr. W. Peile (Whitehaven) said with regard to the probable extension of the coal-field south of Whitehaven, it had always appeared probable to him that the coal-field might extend farther out to sea than Mr. Russell had indicated, and that it might connect with the North Wales coal-field.

Mr. R. Russell said the only question which appeared to him to be of particular moment was with reference to the fault at Brayton. He considered that it was probably not one great fault but a series of faults, and that the fault met with at Brayton, and that on which the No. 4 pit was sunk, was the first of a series of faults which resulted in the whole thickness of the St. Bees Red Sandstone being thrown in. No doubt there was a fault on the south side of the downcast to which he referred; a fault had been proved at Aspatria and also at No. 3 pit, Brayton colliery, in consequence of the exploration made on the north side of the fault. The same fault had been proved at the collieries at Maryport, where the St. Bees Sandstone was thrown down. The main point which concerned the existence or non-existence of the fault was the extremely unfavourable position of the Coal-measures about Crosby.

Mr. Watkyn Thomas (Cockermouth) thought there was one other point of interest. At the Aspatria collieries, the Coal-measures rose eastwards, and at All-Hallows colliery, at a distance eastwards of about 3 miles, the two collieries were on nearly the same level from the surface; so that there must be either a big fault or a series of faults, because the measures dip westwards on an average about 6 inches per yard. Had Mr. Russell any notion of where the fault or faults came in that brought about such changes between these two collieries?

Mr. Russell said there was a parallel series of north-and-south faults crossing the coal-field, the outcrops being repeated again and again.

The President proposed a vote of thanks to Mr. Russell for his excellent paper.

Mr. G. B. Forster seconded the vote of thanks. The subject, which was one of considerable importance, required more thought than a first reading of the paper, and as the discussion would be adjourned he hoped the members would study the printed paper and then give the Institute the advantage of their views.

The vote of thanks was cordially adopted.

To illustrate Mr R. Russell's Paper on "The Extension of the West Cumberland Coal-field, Southward & Northward under the St. Bees' Sandstone."

FIG. 2.—SECTION SHEWING THE UNCONFORMITY BETWEEN THE ST. BEES' SANDSTONE AND THE CARBONIFEROUS AND SILURIAN ROCKS IN THE DISTRICT FROM ST. BEES HEAD TO MUNCASTER FELL.

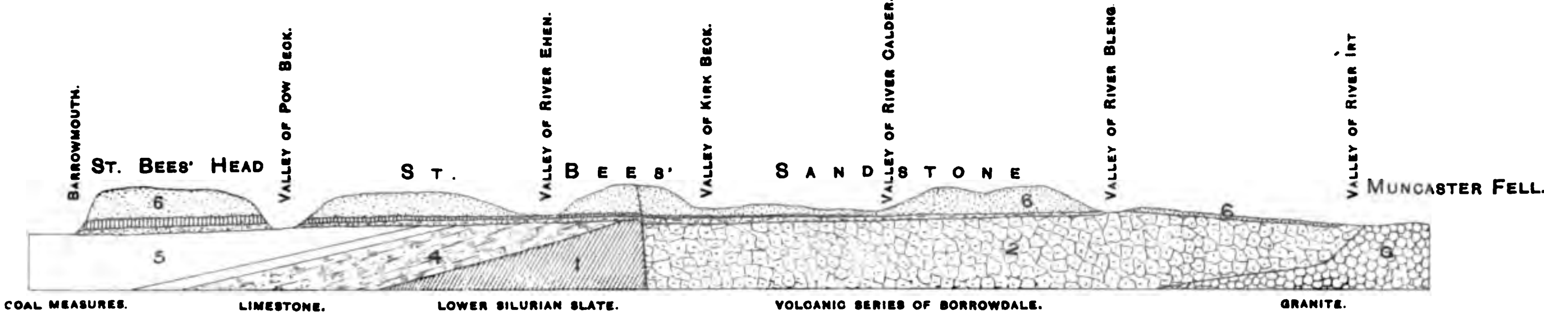
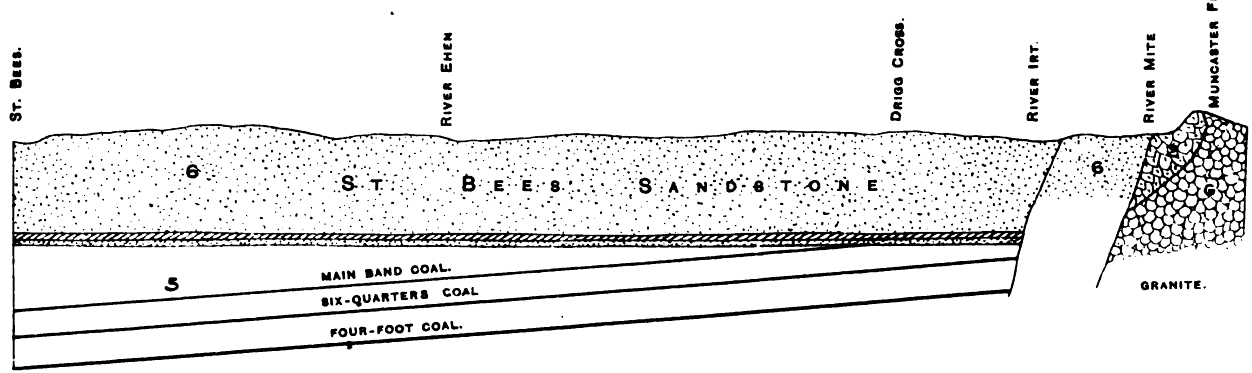


FIG. 3.—SECTION SHEWING THE PROBABLE EXTENSION OF THE COAL-MEASURES UNDER THE ST. BEES' SANDSTONE BETWEEN ST. BEES AND MUNCASTER FELL.



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MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE QUEEN'S HOTEL, LEEDS, NOVEMBER 3RD, 1894.

MR. J. NEVIN, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and signed.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. LEONARD HAMMOND HODGSON, Colliery Under-manager, Garforth, near Leeds.

Mr. HARRY JOHNSON, Mining Student, 3, Richard Street, Wakefield.

Mr. CHAS. PERCY MORTON, Mining Student, Wales Hall, near Sheffield.

Mr. THOS. THOMPSON, Colliery Manager, Featherstone, near Pontefract.

Mr. WALTER J. WOOD, Mining Engineer, c/o Bengal Coal Company, Khuldeah, Giridih, E.I. Railway, Bengal.

The PRESIDENT then delivered his Inaugural Address as follows :—

PRESIDENTIAL ADDRESS.

BY JOHN NEVIN.

To write a presidential address for an Institute of this kind seems to become more difficult from year to year, as we now have in the *Transactions* of The Federated Institution of Mining Engineers six or seven presidential addresses each year, and consequently every subject of interest appears to have been touched upon.

It may, however, be interesting to look back in our own district for twenty-five or more years, when I first began my apprenticeship to mining engineering, and make some comparison with the present time.

In December, 1866—twenty-eight years ago next month—occurred the great disaster at the Oaks colliery, and one of my earliest recollections is of a visit there in January, 1868, when the shafts were being reopened.

At that time the Old Oaks colliery, with 7½ feet shafts 1,000 feet deep, was considered one of the largest and deepest in Yorkshire, and with the exception of Shireoaks colliery, sunk in 1859, and Altofts and Denaby Main collieries, recently sunk, there was, I believe, no pit in Yorkshire over 1,200 feet deep. Five hundred tons a day was looked upon as a fair output for one shaft, and 700 tons was something unusual.

Furnace-ventilation was almost universal; haulage was almost entirely done by horses, except in a few cases, as at the Oaks colliery, where there were single-rope engine-planes to the dip, and except in a few scattered instances, where compressed air was used, no attempt was made to convey power underground.

In 1868, in the Yorkshire district—

The mineral output was	9,705,000 tons.
Mines in operation	459
Persons employed	37,000

Showing 262 tons per person employed, and 21,144 tons per mine.

Lives lost	80

Being 1 per 462 persons employed, and 1 per 121,312 tons raised.

The figures for the United Kingdom being—

Minerals raised	104,566,959 tons.
Mines in operation	3,262
Persons employed	346,820

Showing 301 tons per person employed, and 32,056 tons per mine.

Lives lost	1,011

Being 1 per 343 persons employed, and 1 for each 103,429 tons raised.

The Monk Bretton colliery commenced in 1871 with two 12 feet downcast shafts and one 16 feet upcast shaft, and the length of tubbing was considered a model at that time.

Let us look at some of the work which has been done since.

From 1865 to 1874, a great impetus was given to mining in Yorkshire. New collieries were sunk along all the lines of railway. On the North Eastern Railway east of Castleford, in what was then entirely an agricultural district, collieries were sunk at Wheldale and Frystone which are now down to the silkstone seam. On the Goole branch of the Lancashire and Yorkshire Railway, collieries were opened at every available point from Sharlston to Pontefract, many of which are now down to the silkstone seam from 1,800 to 2,100 feet deep.

Farther south, on the Midland Railway, new collieries were opened out to the Barnsley bed at Monckton, Houghton, Wath, and other places to the dip of the older pits, varying from 1,200 to 1,500 feet deep.

To the west of Barnsley, new pits were sunk through the old workings of the Barnsley bed to the silkstone and other seams at Hoyland, Barrow, and Rockingham.

A few years later, we had the lower seams opened out at Aldwarke, and the deep sinking to the Barnsley bed on the Great Northern Railway at South Kirby, and the last year or two has seen the opening out of the collieries at Cadeby over 2,100 feet deep, and of Rotherham Main and Hickleton.

The figures for 1893 are practically useless, owing to the four months' strike; but taking the year 1892 for the Yorkshire inspection district—

The minerals raised under the Mines Regulation Act were	23,709,072 tons.
Mines in operation	416
Persons employed	86,706
Showing 273¼ tons for each person employed, and 56,993 tons per mine.	
Lives lost	83
Being 1 per 1,044 persons employed, and 1 per 285,651 tons raised.	

Some ironstone and other mines in Lincolnshire, etc., are included in this return which were excluded in the 1868 return.

The figures for the United Kingdom being—

Minerals raised	191,954,908 tons.
Mines in operation	3,403
Persons employed	664,300
Showing 298 tons for each person employed, and 56,407 tons per mine.	
Lives lost	982
Being 1 per 676 persons employed, and 1 per 283,927 tons raised.	

Yorkshire has, therefore, improved its position during the twenty-five years as follows—

	Tons.		Tons.		Per Cent.
The output has risen from	9,705,000	to	23,709,072	or	144·29
The collieries working have decreased from	459	to	416	or	10·33
The persons employed have increased from	37,000	to	86,706	or	134·34
The tons wrought per person employed have increased from	262	to	273½	or	4·39
The tons wrought per mine have increased from...	21,144	to	56,993	or	169·54
The lives lost have increased from... ...	80	to	83	or	3·75

The lives lost have improved from 1 in 462 to 1 in 1,044 per person employed, and from 1 for 121,312 tons to 1 per 285,651 tons.

The corresponding figures for the United Kingdom being—

	Tons.		Tons.		Per Cent.
The output has risen from	104,566,959	to	191,954,908	or	83·57
The collieries working have increased from	3,262	to	3,403	or	4·32
The persons employed have increased from	346,820	to	664,300	or	91·54
The tons wrought per person employed have decreased from	301	to	289	or	4·15
The tons wrought per mine have increased from...	32,056	to	56,407	or	75·96
The lives lost have decreased from ...	1,011	to	982	or	2·95

The lives lost have improved from 1 in 343 to 1 in 676 per person employed, and from 1 per 103,429 tons to 1 per 283,927 tons.

Yorkshire has, therefore, improved its position much more than the United Kingdom at large.

These new openings have been accompanied by great improvements in other ways.

Ventilation by furnace is now almost entirely superseded by centrifugal fans, of which the old favourite forms of large diameter, as the Guibal or Waddle, seem now to be giving way to the smaller and more compact fans of quick-running type, as the Schiele or Capell.

The lighting of the mines has received great attention. The open lights used in most of the less fiery collieries twenty-five years ago gave place first to the Davy or Stephenson, and lately to the safer forms of the Mueseler and Marsaut safety-lamps. For the latter change we are to a great extent indebted to the careful and painstaking experiments carried out at Aldwarke colliery by Mr. C. E. Rhodes, one of the past-presidents of this Institute.

Haulage is now, on the main roads at least, almost entirely mechanical, the method most in favour, where the roads are sufficiently straight, being by endless-rope, with the engines on the surface, and a driving-rope taken down the shaft, thus getting rid of underground boiler-fires or steam pipes in the shafts.

As to hewing or getting of the coal, although many machines have been tried, less headway seems to have been made in this than in any other department; but in a few cases machines are being worked satisfactorily. The great difficulty seems to be in the transmission of the power to the face of the workings. Driving the machines by electricity can hardly yet be considered safe, and there are many difficulties in the way of transmitting the power by ropes, the power generally used up to the present time being compressed air, entailing heavy expense in plant at the surface and in pipes in the mine.

Boilers and engines have been much improved. Double-flued Lancashire boilers, often of steel, working sometimes at pressures of 100 lbs. per square inch, have generally taken the place of the old egg-ended boilers, working at pressures varying from 20 to 40 lbs. per square inch, and mechanical firing is being adopted in many cases.

For winding-engines, the favourite form is the double-cylindered horizontal, directly connected to the drum-shaft, the drum being in some cases spiral, and round steel ropes are almost invariably used.

Sinking has also been much improved, shafts are sunk up to 18 and 20 feet in diameter, which size, with the greatly increased depth, has caused much stronger engines to be necessary for removing the rubbish sufficiently quickly; walling-scaffolds and the arrangements for banking have been improved, and the kibble in the deeper pits is generally run on guides. I believe that Pontefract colliery, sunk in 1873, was one of the first pits in Yorkshire where guides were used during sinking.

Blasting, which cannot be avoided in most pits, has had much attention given to it. Compressed lime-cartridges for coal-work were tried for some time but did not prove very successful. At present for stone-work, gunpowder is rapidly giving way to the new forms of more or less flameless explosives, such as ammonite, roburite, etc., each of which has its supporters and is claimed to be the best.

Electric lighting has also been largely introduced of late years.

Banking and screening arrangements have received great attention, the pit-hills are now raised higher, and the old fixed bar-screens are giving way to moving-screens with picking-belts on which to clean the coal.

For coking, the beehive oven still holds its own with various improvements, and we have in Yorkshire at least one very good example of the saving of the bye-products.

Unfortunately, in spite of all the care which is taken we cannot entirely get rid of explosions, as witness that at Thornhill in July, 1893.

Probably in no part of England has more good work been done during this quarter of a century than in Yorkshire, and, so far as one can see, the next twenty-five years will show an equal advance. The coal-field has many advantages, its chief disadvantages, as compared with the collieries farther north, being the distance of most of the pits from a shipping port, and the custom of only working a single shift, which causes the enormous capital of many of the larger pits to be practically productive for not more than forty-eight hours a week, while the expenses are running for 168 hours.

In Yorkshire we have not often the opportunity, as in Northumberland and Durham, of working several seams of nearly the same quality lying near together, thus at Ashington colliery five seams are all being more or less worked at the present time, the deepest of which is no more than 500 feet from the surface.

Such being the advance made in this district in the past, what has the mining engineer to look forward to?

He will have to contend with increasing difficulties which will meet him in working the thicker seams at great depths and the thinner and inferior ones at moderate depths (which have been left as unprofitable by his predecessors), and he will have to meet the growing demands of the workmen for higher wages and shorter hours, and last, but not least, a steadily increasing foreign competition.

Foreign competition, although scoffed at by some people, is no myth. Probably in Europe no country except Germany can do us much harm; but farther afield we have large coal-fields in Australia, the extent of which has by recent explorations been proved to be much greater than was hitherto suspected. In Japan, are extensive mines, and the large coal-fields of Borneo and China are almost untouched.

Already these fields supply most of the merchant steamers in the East Indian trade.

But probably our great competitors eventually will be the North American colonies and the United States. In the latter country, as I have seen myself, besides the almost unique deposits of anthracite in Pennsylvania, there are in Alabama, Ohio, and other central and western states, square mile after square mile of Coal-measures, containing often ten or twelve seams of good bituminous coal, from 3 to 8 feet thick, lying nearly level, with few faults, and free from water, being above the bottom of the valleys by which the country is intersected.

These coals can be worked to a profit, and the round coal put into railway-waggons for less than 4s. per ton, the small coal being left in the

mine, and only the great distance from the Atlantic coast prevents them from being put on to our markets in England. They are, however, delivered at the Atlantic ports at a price nearly if not quite as low as English or Welsh steam coal at Liverpool, and are being largely and increasingly used by the Atlantic steamers.

In deep mining, the chief difficulties seem to be, firstly, the great pressure of the superincumbent rocks, amounting roughly to 1 pound per square inch per foot of depth, which makes the roads and openings difficult to keep open, and which has a tendency to crush the coal and cause it to make much small in the working; and, secondly, the increased temperature.

The first difficulty can be best met by working on the longwall system and pushing the working-faces forward as quickly as possible, the second, by ample ventilation; and it will probably be found useful in some cases, if one or more districts have longer airways than the rest, to put a supplementary fan underground to assist the main one at the surface.

The surface-plant and workings must be arranged so that very large outputs can be dealt with at the least possible cost, so as to pay interest and return the large amount of capital expended; and the plant should be so designed as to be able to work other seams when those for which it was originally intended are exhausted.

As the working-places get farther and farther from the shafts means will have to be taken to convey the men quickly to and from their places without fatigue. Walking long distances underground, like climbing ladders in metalliferous mines, is a waste of labour which will sooner or later be abolished, and machinery will have to be used, wherever possible, in place of human muscles.

In working the thinner coal-seams, even at less depths, not less skill will be needed. The problems of great pressure, large amounts of gas, and high temperature will not be so pressing, but the necessity for putting down plant to raise large outputs and to work large areas with the greatest possible economy, will be still more urgent. If our comparatively new friend, the electrician, will give us motors and conductors absolutely free from sparking under all circumstances, so that power can be safely and cheaply conveyed into every corner of a mine, a great part of the problem will be solved. Given such a means of transmitting power, coal-cutting machines will soon be used, especially in such seams as the thin cannel coal-seam in West Yorkshire, where the output per collier does not in some cases exceed 1 ton per day—a very poor result for a large expenditure of human labour.

The haulage in a thin seam should, with very few exceptions, be entirely mechanical, so as to save as much as possible the cost of making horse-roads, and the workings should be centralized as much as possible, so as to keep at a minimum the roads open in proportion to the output, which is of necessity much less per acre of workings than in a thick seam. Care should, however, be taken where possible to have at least two main roads coming to the shaft-bottom, so that the whole output of the pit is not stopped should any accident occur in one of them.

Every care will have to be taken also to clean the coal both underground and above, and to utilize every scrap of it by coking, making briquettes, etc.

Fortunately, with increasing difficulties, we have now greater facilities for meeting them.

The facilities for the education of a young man wishing to become a mining engineer have been very much improved during the last twenty-five years. Nothing will do away with the necessity for underground experience, and the absolute need for a young man to see and become practically acquainted with every detail of the work which will have to be carried on under him, from the making of the leases and the plans, the laying out of surface-plant and underground workings, to a knowledge of the amount of work which can be done by the smallest hurrier-lad, and the proper use of even a brattice-nail.

This, and also that most important part of a mining engineer's education, the management of the workmen under him, without which no man can be successful, can only be learned by daily routine at a well managed colliery.

There are now, however, facilities for learning the theoretical part of the profession which twenty-five years ago did not exist. I allude to the technical colleges, of which the Yorkshire College at Leeds and the Firth College at Sheffield are such good examples, to the various technical schools which are now to be found in every large town, and to the lectures promoted by the county councils in almost every village.

Another great step in advance has been made by the Federation of the various Mining Institutes, by which a member of one of the Federated Institutes has access to the *Transactions* of the whole of them, and thus acquires a knowledge of all the newest and best work done in his profession throughout the country.

With all these increased facilities, I think we may rest assured that Yorkshire will be able to keep up and even improve the place which she now holds among the coal-producing districts of this country and of the

world; and I hope she may become even in a greater degree than she is now, as Durham and Northumberland have been and still are, a nursery for mining engineers and colliery managers for the whole world.

In the earlier days of the North of England Institute of Mining and Mechanical Engineers, after some of the more serious accidents, such as those at Burradon and Hetton in 1860, and New Hartley in 1862, papers were read describing the accidents and the means taken to reopen the pits, etc. Such papers and the discussions on them are of great value, and I wish that we could have this plan carried out; and although there are difficulties in the way now which did not exist then, I think it should still be possible.

I should at any rate very much like to see a suggestion carried out which was made last year by our late President, Mr. W. E. Garforth, that is, that a small committee should be formed to draw up suggestions as to what is best to be done in such cases. I think that something of this kind would be very useful, as it often happens that it is some time before any one who has had experience of such matters can be obtained, and there are always plenty of willing workers if any one can be found to direct them to the best advantage.

Mr. Hargreaves (Rothwell Haigh) hoped that the President's suggestions would be acted upon, as it might be the means of saving valuable lives. He moved that the best thanks of the members be given to the President for his address.

Mr. Nash (Barnsley) seconded the motion, which was carried unanimously, and briefly acknowledged.

The Secretary read the following notes by Mr. E. W. Thirkell on "A Detaching-hook used at the Sinking Pit at the Old Oaks Colliery":—

A DETACHING-HOOK USED AT THE SINKING PIT AT THE OLD OAKS COLLIERY.

By E. W. THIRKELL.

The two capstan-ropes *A B*, on which the bricking-scaffold is suspended, are used also as conductors, a monkey or stay of wrought iron *C*, being used to keep the trunk steady (Fig. 1.)

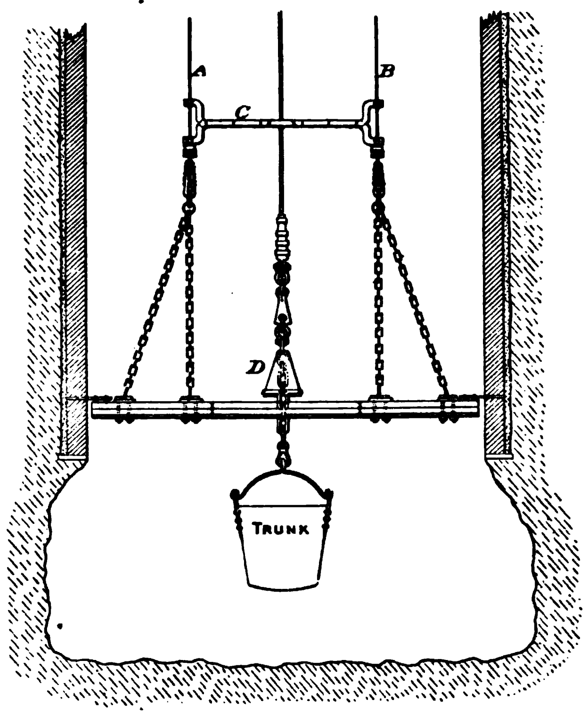


Fig. 1.

In order to use both monkey and detaching-hook, a cone *D*, was made to cover the chains, etc., and so constructed as to carry the monkey on a shoulder left on the cone for that purpose. The combined arrangement acts admirably. Without some such contrivance it would have been difficult to use a detaching-hook, and it was very desirable that one should be used during the sinking. In case of the trunk being overwound, not only would great damage be done by the trunk falling down the shaft, but—and this is of course the principal thing—the sinkers below would be in very great peril of their lives.

The Secretary read the following notes by Mr. E. W. Thirkell on the "Safety-lamps used at the Oaks Collieries":—

SAFETY-LAMPS USED AT THE OAKS COLLIERIES.

By E. W. THIRKELL.

The safety-lamps in use are the Protector Mueseler, fitted with a tin-shield, and gas oil is used as the illuminant.

Thorough inspections of every part of the safety-lamps are made by the repairer every five weeks. By this means slight defects are detected, and can be attended to before they get into a dangerous condition. This inspection takes two days, one day for the locks, threads, etc., and the other for the gauzes and top part of the lamp. In order to keep every part of the lamp under notice a record is kept of the life of each part.

RECORD OF THE LIFE OF THE VARIOUS PARTS OF THE MUESELER SAFETY-LAMP.

Reference Marks.	Names of the Parts.	Per Annum during 1888 and 1889.	Per Annum, 1892.	First Half of 1894.
A	Wire hooks	0·070	0·071	0·048
B	Eyelets	—	—	0·014
C	Iron tops	0·071	0·038	0·012
D	Iron standards	0·009	0·005	0·004
	Leaden plug-bolts	—	—	0·047
E	Brass standards	0·084	0·012	0·010
F	Top gauzes	0·340	0·530	0·240
	Shields	0·380	0·440	0·210
	Permanent cotton wicks...	0·330	0·220	0·070
	Sponges	0·084	0·021	0·008
G	Chimney and horizontal gauze	0·590	0·330	0·160
H	Middle body	0·006	0·008	0·008
H¹	Gauze ring	—	0·008	0·005
H²	Glass ring	—	0·016	0·004
I	Extinguisher	0·073	0·170	0·050
	Worm-screw	0·083	0·150	—
J	Brass screw-plate...	0·067	0·117	0·050
K	Outside bottom (oil vessel)	—	0·012	0·009
	Glasses	1·240	1·810	0·820
	Asbestos washers for top and bottom of glass	—	0·010	0·440
L	Inside bottom (oil vessel)	—	0·012	0·012
N	Bottom lock, excluding leaden plug and bolt	—	—	0·006
N¹	Fork and spring of lock	0·110	0·063	0·025
N²	Cover for feed-hole of oil vessel... ...	—	—	0·003

Safety-lamps used in wet places receive special attention, and are opened and cleaned immediately on being handed in at the lamp cabin. The gauzes are first brushed in the usual way, and afterwards with a little black-lead, which acts as a preventive against rusting, and gives them a better appearance. A little tallow applied with a cloth or brush

to the frame of the lamp preserves it from rust, and makes it more easily cleaned. Every part of the lamp is numbered, so as to avoid the risk of mixing when putting them together. The number of lamps put out for each district of the mine is recorded every day, and this shows where careless usage exists. Instructions are given that the remarks in the lamp-keeper's report book shall be as detailed as possible, particulars being given as to all damage done to the safety-lamps. In every case where lamps are damaged, the person who has done the damage is seen by the manager personally, who by this means is bound to know whether proper care is being taken by those using the lamps. Before being handed to the workmen each safety-lamp is tested in gas, in a mixture as similar as possible to that found in the mine.

Mr. Hargreaves (Rothwell Haigh) thought that safety-lamps ought to be thoroughly examined more than once in five weeks, and that they should be tested in gas daily before being allowed to go down into the pit.

Mr. A. A. Atkinson (Barrow Collieries) said that there seemed to be some misapprehension about this matter. The safety-lamps were inspected daily. Mr. Thirkell referred to a more special examination, to ascertain the condition of the lamps, screws, threads, etc.

Mr. Hargreaves said that five weeks was too long a period for a safety-lamp to be in use without being taken to pieces.

Mr. Nash said that each lamp was taken to pieces every day at the Oaks collieries, and tested as thoroughly as at any other place, and there was in addition a special examination to replace defective parts.

Mr. Turnbull said that 900 safety-lamps were in daily use at the South Kirkby colliery, and they were daily tested in gas to the point of extinction. The lamps were cleaned in the usual way when they were brought in by the workmen, and then put on the shelf ready for issue to the workmen on the following day.

Mr. T. W. H. Mitchell (Barnsley) said that the members would remember that at Aldwarke colliery the flame of nearly every safety-lamp was wafted and flickered before the lamp exploded. Taking that view of the question, they had made a practice at Mitchells Main colliery of testing the safety-lamps in a current of air travelling at the rate of 25 feet per second, and if the flame flickered the lamp was put on one side for examination. They had a certain number of safety-lamps in use which

could be lighted by electricity, and they found it a great convenience. These lamps were tried in the air-current and put out and on one side. When the workmen came for them they were placed on the poles of the electric battery and lighted. They were thus never reopened after being tested. They had not yet gone into the question of cost, but the saving of oil as against lighting them some time beforehand was considerable. Then, again, in the pit a battery could be placed in the care of a workman at a pass-by, and if a lamp was extinguished, it could be taken there and relighted. The system seemed to be working very well. Colzaline oil was used.

The following paper by Mr. James Bowers on the "Hargreaves Balanced Slide-valve" was taken as read:—

HARGREAVES BALANCED SLIDE-VALVE

By JAMES BOWERS.

To attempt to describe all the methods which have been adopted to balance slide-valves would be a considerable task.

In the years 1890, 1891, and 1892, upwards of twenty patents were taken out for balancing slide-valves. In some the steam was admitted from the underside of the valve into a chamber formed by a cylinder and piston fitting into each other, having plates working against the valve-face and steam-chest cover. In others there was an arrangement of double-ported valves open through and having a stationary port-valve fixed to the cylinder-cover, the steam partially balancing the valve so long as the faces were in perfect contact. Several inventions consisted of various arrangements of pistons and cylinders fitted with packings and springs, some travelling with the valve and others attached to the steam-chest cover, and the valve moving beneath.

All the above-mentioned appliances and other devices seen by the writer appear to be objectionable owing to the number of loose working parts depending on spiral or other springs, and in some cases packing-rings to keep them steam-tight and in working order. These are all covered up in the steam-chest and cannot be examined, and no means are provided for ascertaining if they are acting whilst running; they often become non-effective through parts becoming fast, which cannot be found out without taking the parts to pieces when the engine is standing.

In the Hargreaves anti-friction or balanced slide-valve (Figs. 1, 2, and 3) the ordinary slide-valve *A* is planed on the back to a true surface, and upon this is placed the plate *B* and piston *C*, cast in one piece, the piston working in the cylinder *D*, which is cast in one piece with the steam-chest cover *E*.

A slightly elastic copper diaphragm-plate *F* is fixed to the piston *C*, and the cylinder *D*, in which are a series of grooves, *G*, *G*. The steam has free access by the grooves to the recess *H*, and its pressure is exerted upon the exposed surface of the copper-plate.

The difference between the area of the recess H and the area of the back of the plate B is the total area acted upon by the steam-pressure, and

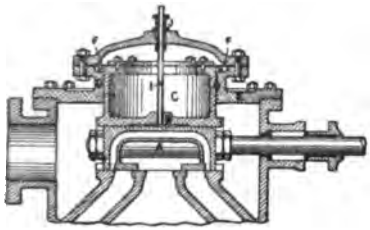


FIG. 1.

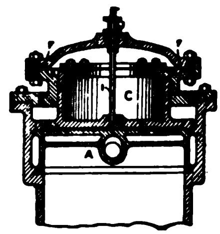


FIG. 2.

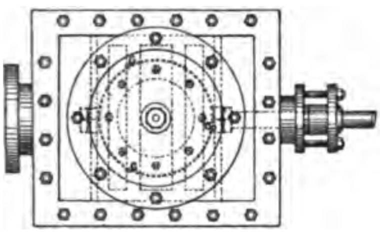


FIG. 3.

is just sufficient to keep the valve to the face. Should any steam find its way between the plate B and the slide-valve A, it immediately escapes through the pipe I. This pipe also prevents the copper-plate from being strained by any sudden shock from back-pressure which may occur in winding engines, when, in reversing, the steam is turned suddenly on to the opposite end of the cylinder. This purpose is effected by the screw J in the cover being screwed down on to the collar of the pipe I, so as to allow the copper-plate to have a slight movement.

The following paper by Mr. James Bowers on the "Hargreaves Piston" was taken as read :—

HARGREAVES PISTON.

By JAMES BOWERS.

The Hargreaves piston-packing, shown in Figs. 1, 2, and 3, is different from any other that the author has seen, and when put together with the piston forms a perfectly solid block. The piston is purposely shown (Fig. 1) as not fitting the cylinder, so as to indicate that the whole work is done by the rings, and that the weight of the piston and moving parts is sustained entirely by the rings. In the case of a cylinder having been rebored, say ½ inch larger in diameter than the original size, the use of this packing will obviate the necessity of making a new piston body to fit the cylinder, as would probably be the case with any of the ordinary packing-rings. Another feature of the piston-rings is that the wear is equal in all directions, and consequently the cylinder is kept true and the piston maintained in its proper position; and in cases where the piston has been fitted into an oval cylinder in a short time it has been brought again to its proper circular shape.

The two inner rings (Figs. 1, 2, and 3) are solid at their circumference, and are bored out to fit easily on to the piston body. A number

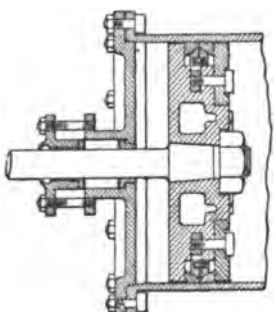


FIG. 1.

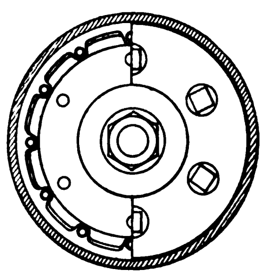


FIG. 2.

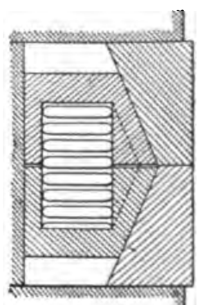


FIG. 3.

of bosses are cast round the inner rings in which spiral springs are fitted, varying in number and strength according to the size of the rings. The outside of the inner rings is tapered to an angle of about 75 degs., and the outer rings are tapered correspondingly. The outer rings are cut in the usual way, and as they become worn the spiral springs press the two inner rings apart, keeping the outer rings pressed up against the walls of

the cylinder and the sides of the piston and junk-ring. It will, therefore, be seen that unlike other packings with compound spiral springs which have to sustain the weight of the outer rings and also keep them tight, the springs in the Hargreaves piston follow up the wear of the rings, the whole weight being borne by the rings themselves.

This packing is well adapted and is extensively used for piston-valves, as the steam cannot compress them when passing the ports.

Mr. J. E. Chambers (Tinsley) moved a vote of thanks to Mr. Bowers for his papers.

Mr. Nash seconded the motion, which was agreed to.

DISCUSSION ON MR. R. ROUTLEDGE'S PAPER ON "DAMAGE DONE BY LIGHTNING TO THE SURFACE WORKS AT GARFORTH COLLIERY."*

Mr. A. W. Bennett (Leeds) said that the effects apparently of a single flash or possibly two or three rapidly following flashes of lightning at the Garforth colliery might be summarized as follows :—

1. On the lightning-conductor which is attached to the chimney.
2. On the compressed-air pipe which was supposed to have been cracked, but was found to have merely had a groove cut in it, probably by the lightning-conductor end that became detached from the earth-plate and was thrown up past the pipe, ripping up the ground.
3. On the pit headgear. A flash or apparent ball of fire going down the pit; a flash also being seen at the pit bottom.
4. On the telephone and signal-wires, both of which appear to have formed a path for the lightning-discharge; the telephone (probably on account of using earth as a return for its circuit) being injured, whilst the signals were not affected.
5. The winding engineman received a slight shock.

The inferences that may be drawn are :—

1. That the storm or at least the flash was an unusually severe one.
2. That some attractive and possibly immediately afterwards repulsive force existed between the end of the lightning-conductor in the ground and the air-pipe.

* *Trans. Fed. Inst.*, vol. viii., page 64.

3. That the lightning-conductor became much heated, causing it to become pliable at the top of the tape where, the holding set screw being loose, it dropped out of the fitting connecting it to the top-rod and points, probably also releasing the tape from its connexion with the copper-plate in the earth. The air-pipes were laid after the lightning-conductor had been erected. It is now impossible to test the connexion to earth or what its electrical resistance was before the storm.
4. That by some means the flow of electricity from earth to cloud and cloud to earth, took, as an alternative path to the lightning-conductor, the pit-gearing, and thus passed to earth through the winding-engine, steam-pipes, air-pipes, and the air-compressor; another path being through the guides and ropes to the pit-bottom; and two other paths through the telephones in the lamp-cabin and in the pit respectively.

The most serious matter was, of course, the lightning flash going into the pit, and he had worked out approximately the electrical resistances of the lightning-conductor and the pit-guides and ropes respectively. Assuming the distances by the copper-tape conductor to earth to be 100 feet and by the ropes, etc., 500 feet, taking the sectional area of the ropes and guides at 4 square inches and the copper-tape at 0·125 square inch, the resistance of the 500 feet of iron ropes was 0·0074 ohm and of the 100 feet of copper-tape was 0·0073 ohm, the resistances being practically the same, supposing that the resistance from metal to earth was in both cases practically *nil*. The height of the chimney was about 100 feet, against a height of 50 feet for the head-gear (to the top of the wheel), while the distance from the head-gear to the chimney was about 150 feet. If the electrical charge in the cloud were directly over the wheel, or in the opposite direction from the chimney and not at a great height, then the head-gear might form the shortest path. The lightning-conductor, provided with points and making good earth, should draw the cloud to itself, and if the charge were not very great it might be neutralized or discharged by what is known as a brush discharge. In the present case, however, the connexion to these points was not good, and the earth-connexion was at least rather doubtful; therefore, it would seem as if the head-gearing may have been the path of least resistance to earth. As a probable means of obviating or at least minimizing the dangers he would suggest:—

1. That a lightning-conductor of ample area of best copper rope or tape, with large top-rod or tube of ample section, and large points preferably tipped with platinum should be adopted.

2. If connected to an earth-plate that the plate be large, and that the connexion be made as perfect as possible.
3. The thorough testing of the conductor for conductivity to earth immediately after erection and at regular periods.
4. The lightning-conductor should be connected, if possible, to steam, air, gas, or water-pipes, and also to the pit-head gearing in the best possible manner, so as to ensure a continuity of exceedingly low resistance and large area to earth at the surface.

He also advised that one or more copper points (with tape led from them to the same earthing-system) placed upon the head-gear might be found of advantage, especially if the gearing be far from the main lightning-conductor, the idea being that wherever the electrical charge in a cloud may be it may get to earth by paths of much lower resistance than those going into the pit. That such exist not merely in theory but in fact can be ascertained by regular periodical tests.

5. The telephones should have metallic circuits, with both the wires insulated, where communication is made from the surface into the pit, so as to increase the safety.

Mr. NASH asked how the conductor was to be tested?

Mr. BENNETT said that the testing would be made for continuity to earth, or for the least electrical resistance from the lightning-conductor to earth, which seemed to him the most likely part to become faulty.

Mr. NASH said that he understood Mr. Bennett to be of opinion that the fault lay between the connexion at the top of the chimney and the connexion to earth.

Mr. R. ROUTLEDGE said that if the conductor had been broken previously, it would have been seen, just as after the accident they could see the end hanging from the ground. He thought that part of the current had got past before it broke, and when the air-pipe was taken up, instead of being broken it was found to be merely grooved.

Mr. J. ROUTLEDGE thought that the connexion with the earth must have been a good one, or the ground would not have been ripped up. He remembered a case where a chimney was struck by lightning some years ago, and the conductor was found in working order afterwards, and yet the chimney was broken and the ground ripped up.

The PRESIDENT said that in that case the conductor had not been large enough to carry the current.

Mr. BENNETT said it seemed to him that the fact of the earth having been ripped up indicated that there must have been great force there, and as a rule in electrical systems they found the maximum force where the

resistance was greatest. The earth was ripped up because the conductor was in good order, but the connexion to earth for so large a current had been insufficient.

Mr. H. Bonser (Leeds) understood that Mr. Bennett recommended the use of auxiliary conductors.

Mr. Bennett said that was so.

Mr. Turnbull was doubtful as to the value of lightning-conductors, as he had noticed that all places which had been struck by lightning had been fitted with lightning-conductors. He had not seen a place struck by lightning where there had not been a conductor.

Mr. R. Routledge said that the chimney struck by the lightning had been built and fitted with the conductor for five years. There was another chimney 115 feet high, which had been built for sixty years, and had never been injured by lightning.

Mr. Hodgson (Garforth) said he had always been under the impression that there were three kinds of lightning—forked, sheet, and ball lightning. The accident at Garforth colliery was due to ball lightning, and he understood that there was no method of conducting ball lightning.

Mr. Bennett said that the question of sheet, forked, or ball lightning resolved itself into a question of how far the cloud carrying the electricity was distant from the earth. In the case of sheet lightning, the electricity went from one cloud to another; in the case of forked lightning the charge went from the cloud to the earth; ball lightning was a form where the cloud or source of the lightning was close to the earth. Its occurrence would also support what they already knew, that the current did actually go down the head-gear.

Mr. H. Bonser said he had tested the earth-connexions with a galvanometer ordinarily used for testing fuzes. For an earth-connexion he recommended that the copper wire conductor should be run 50 to 100 feet in the ground, and that a barrowful of scrap-iron should be placed at the end; this would form an excellent earth-connexion, and the scrap-iron would distribute any current which might come down the conductor. Formerly, they were told that it was necessary to detach the tape from the building by means of insulators, but now they were told that it should form part and parcel of the building, so that ideas had altered considerably about lightning-conductors in recent years. The earth-connexion might be tested by a galvanometer at any time.

Mr. R. Routledge said that the conductor which he had mentioned was taken a distance of 12 feet from the chimney and laid against a metal pipe.

The discussion was then adjourned.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE ROYAL VICTORIA HOTEL, SHEFFIELD, DECEMBER 15TH, 1894.

MR. J. NEVIN, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—
Mr. FRED. BAGSHAWE, Agent of Wire-rope Manufacturer, 4, Ashgrove Headingley, Leeds.
Mr. ALBERT BEARD, Colliery Manager, Carlton Main Colliery, Barnsley.
Mr. WILFRED BUTTERLEY, Colliery Manager, North Gawber Colliery, Barnsley.
Mr. ALFRED LYMN, Mining Engineer, Fir Tree Cottage, Ince, Wigan.

DISCUSSION UPON MR. T. H. WORDSWORTH'S "NOTES ON COAL-GETTING BY MACHINERY."*

Mr. M. H. HABERSHON (Thorncliffe) said that it would be interesting to know the amount of power requisite to drive the machine before and after the increase of the diameter of the cutter-wheel, and the alteration in the thickness or depth of the holing. He understood that the machine described cut a greater thickness than previous machines. The paper stated clearly the ratio of the gearing, but there was no statement made as to the number of revolutions made by the cutting-wheel. He also asked whether the writer of the paper had made tests as to the amount of air pressure at the machine itself, or in the 2 inches iron pipes leading up to it?

Mr. W. E. GARFORTH said that no indicator-diagrams had been taken on the machine, owing to its oscillation when working. It was difficult to say what power was required to drive a coal-cutting machine, as

* *Trans. Fed. Inst.*, vol. vii., pages 149, 260 and 495.

it worked much quicker when going through soft coal than when cutting in hard coal. He would however consider whether an indicator could be put to the machine. Last week the machine cut 1,800 feet in one week of two 8 hours' shifts daily. A greater distance had been cut than that on several occasions. The machine made greater progress when working at 33 lbs. to 35 lbs., with air supplied from 9 inches pipes than with 45 lbs. pressure when supplied from 6 inches pipes.

Mr. M. H. Habershon asked what length of 2 inches pipes was in use?

Mr. W. E. Garforth said that the machines had been supplied with air travelling through more than 15,000 feet of pipes. Iron pipes and portable armoured pipes were used.

The President said it would be interesting to ascertain the pressure on the piston.

Mr. T. H. Wordsworth said that the pressure on the iron pipes, next to the flexible tube, was 45 lbs. with one machine working; when three machines were working there was rather less pressure.

Mr. W. E. Garforth said that they had found great benefit from enlarging the pipes from 6 to 9 inches in diameter. They found that it was quite as easy to drive the large as the small wheel.

Mr. C. E. Rhodes asked what was the speed of the engine?

Mr. T. H. Wordsworth said that the speed varied from 100 to 200 revolutions per minute.

The President said that gave 4 to 8 revolutions of the cutting-wheel per minute. With the 5 feet cutting-wheel, the distance from the pack to the nearest row of props would be at least 9 feet. The increased depth of the cutting-wheel meant a longer length of roof unsupported.

Mr. T. H. Wordsworth said that the distance did not exceed 8 feet. The machine would go in a width of 3 feet easily.

Mr. C. E. Rhodes said that the cutter would be 4½ feet inside the coal.

The President said that the cutting would be spragged.

Mr. T. H. Wordsworth said that the speed of the machine did not appear to be in the machine itself so much as in the number of workmen following it. They could easily cut from 150 to 250 feet per shift, if they sent three instead of two workmen.

Mr. W. E. Garforth said that the men working the 4½ feet machine could not earn as much by a shilling a day as the men with the 5 feet machine.

Mr. C. E. Rhodes said that the difficulty with all cutting-machines appeared to be that they must be applied in a seam which was exceptionally

suitable with regard to roof, regularity of the floor and other natural conditions which were not always available. The machines might be a great success at one place, but it did not follow that they could be made a success generally. In Mr. Garforth's case and at the Lidgett and Wharncliffe Silkstone collieries, the machine was a great success; but where there were difficulties with a bad roof and they could not get a straight line of face, or if there were difficulties with regard to faults, it seemed to be impossible to apply machinery for holing purposes with success.

Mr. W. E. Garforth agreed with Mr. Rhodes' remarks. The coal-cutter worked successfully in the new silkstone seam; but in the other part of the silkstone seam, which lies at a greater depth, the machine would be buried before it had worked many minutes. In the Stanley main seam, it could not be used because the holing was made in the middle of the seam; and in the Haigh Moor seam, it could not be worked so successfully owing to the thick clod on the top of the coal.

Mr. C. E. Rhodes suggested that a member should be requested to read a paper on heading-machines, so as to follow up this discussion on holing-machines.

Mr. H. B. Nash (Barnsley) said that heading-machines were used at Cortonwood and other collieries.

The discussion was then adjourned.

INTERNAL FLAWS IN STEEL.

Mr. Thomas Andrews (Wortly Ironworks, Sheffield) submitted a series of twenty-four drawings illustrative of the subject of internal flaws in steel. He was seeking to find out the cause of the internal and hitherto unknown flaws in steel and iron forgings, which had led to those so-called mysterious fractures. He had been devoting attention to the study of the deterioration of fatigue in metals; studying not only temperature, but stress. He had been working with high microscopical powers in studying the interior of large propeller-shafts and various constructive metals. The question of the deterioration of fatigue in metals was not only an important one, but it was very difficult to study. If they could have a perfect metal there should be no deterioration of fatigue—that was the basis of his researches. Every metal was however more or less imperfect, and having to deal with imperfect things, the first thing that the metallurgist had to do was to find out the ultimate cause of this deterioration of fatigue. Up to the present time, they had been dodging about in an empirical manner, saying this or that was the cause of the

fracture, without having any exact information to guide them. He hoped to shed some light on this subject. He thought that he had got a clue to the cause, and, having ascertained that, the next thing was to minimize the effect of these flaws in existing structures; and the third and most important matter was to do away with all these internal flaws if possible in all new work.

Mr. C. E. RHODES asked if the steel or iron tested had been made from ordinary ingots?

Mr. ANDREWS said that some of the pieces were taken from large propeller-shafts, 36 feet in length and 12 inches in diameter; some from English, Scotch, and Belgian railway-axles; some from English, and other tyres; some from boiler-plates; and others from all kinds of constructive work, including heavy steel guns, shells, etc.

Mr. C. E. RHODES asked if there was any marked difference between the result of these fractures taken from propeller-shafts or any large forging as compared with smaller forgings or chain-links?

Mr. ANDREWS said that there was a difference. He had recently sent to Sir George Stokes, of Cambridge, for communication to the Royal Society of London, an account of a discovery which it had been his privilege to make on the effect of cooling of large masses of metal. In the course of his observations on the cooling of large masses of metal from a white heat to an ordinary temperature, he had been fortunate enough to discover a subcrystallization of the metal, so that iron was divided not only into the primary crystals, which had hitherto been regarded as the primary structure of the metal, but was subdivided into more minute crystals still, and those crystals were so minute that a cubic inch of metallic iron in a forging or large shaft would contain no less than 1,000,000,000 of these minute crystals of the secondary division which he had just discovered. This fact might have an important bearing on this deterioration of fatigue. Prof. Arnold, of the Sheffield Technical School, had shown that by increasing the percentage of sulphur in steel, that the true crystals of metal segregated in distinct areas, while the sulphide of iron occupied the spaces between the true crystals of the metal. Sulphur was the great enemy of steel, and Prof. Arnold had been investigating the subject recently; and, though Prof. Arnold's researches and the authors were conducted on somewhat different lines, he was glad to say that they agreed generally in their conclusions. The action of phosphorus was also very detrimental in steel or iron.

A vote of thanks was accorded to Mr. Andrews, after he had explained his drawings.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
OCTOBER 22ND, 1894.

MR. R. H. COLE, RETIRING PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected :—

MEMBERS—

Mr. MORGAN W. DAVIES, Mining Engineer, 17, Adelaide Street, Swansea.

Mr. JOHN GREENE, A.R.S.M., Mining Engineer, Priors Lee, Shifnal, Shropshire.

Mr. ROBERT HART, Colliery Manager, Apedale, near Chesterton, Staffordshire.

Mr. GEORGE E. NAYLER, Surveyor, Springwood House, Chesterton, Staffordshire.

The report of the Council was read as follows :—

ANNUAL REPORT OF THE COUNCIL.

The Council have pleasure in presenting their Annual Report. Seven general meetings have been held during the past year, at which papers on the following subjects have been contributed :—

"Safety-lamps with Standard Flames for Keen and Accurate Gas-testing." By Mr. J. Ashworth.

"Description of Pumping-engines at the Hatton Pumping-station of the Staffordshire Potteries Waterworks Company." By Mr. T. M. Favell.

"The Melling Steam Reversing-gear." By Mr. John Heath.

"Notes on Mr. R. H. Wynne's Paper on the Application of Mechanical Arrangements in Underground Operations." By Mr. T. V. Hughes.

"Stoppings on Underground Roads." By Mr. E. B. Wain.

"Notes on the Practicability of Working the Thin Coals of North Staffordshire by the Adoption of Mechanical Appliances." By Mr. B. Woodworth.

"The Application of Mechanical Arrangements in Underground Operations." By Mr. R. H. Wynne.

Discussions have also taken place upon the various subjects brought forward.

An excursion to the Hatton Pumping-station of the North Staffordshire Potteries Waterworks was made on July 18th.

The Technical Instruction Committee, in conjunction with the Staffordshire County Council, have also had several meetings, and have arranged lectures and classes for the present session. The result of the examination on May 12th last (Messrs. W. N. Atkinson and R. H. Cole being the examiners) was that 10 studentships of £2 and 10 of £1 each were awarded. It is interesting to know that several of those who were awarded these studentships have since obtained certificates of competency under the Mines Regulation Act.

Ambulance classes have also been formed at upwards of twenty different centres.

The number of members on the register, with those elected to-day is as follows:—

Life Member	1
Honorary Members	6
Federated Members	161
Students	15
	183

or an increase of 1, as compared with last year. Six new members and 2 students have been elected, and 7 have either resigned or have been struck off in accordance with the rules.

A very complete General Index of the *Transactions* up to Vol. XI. has been kindly compiled by Mr. Hugh R. Makepeace, and our hearty thanks are herewith accorded to him for the same. A new catalogue of the books in the library is now in the press.

Members are requested to pay their current year's subscriptions promptly, as the *Transactions* cannot be supplied to any member until his subscription is received, without the risk of an absolute loss to the Institute.

The Council feel that much more might be done by a better attendance at the meetings, and the introduction of new members.

FINANCE REPORT.

This report, owing to the alteration in the date of the termination of the financial year, viz., from December 31st to July 31st, so as to terminate at the same time as that of The Federated Institution of Mining Engineers, which was joined in 1892, deals with the receipts and expenditure from January, 1892, to July 31st, 1894.

It was considered at that time that an increased subscription of 5s. per member would cover the extra expense incurred, but this sum falls a long way short of the actual cost.

The total receipts from subscriptions, arrears, and interest for the above period amounted to £638 10s. 6d, and the payments to The Federated Institution of Mining Engineers to £542 16s.

This was inclusive of £42 9s. 2d., being extra calls of 2s. per member for the years 1893 and 1894.

The subscription paid by the members of this Institute is 5s. 6d. less than is paid by the members of any other Federated Institute, and the question of making up this deficiency is one that the Council and members will have to consider at an early date.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.
DECEMBER 31ST, 1892, TO JULY 31ST, 1894.

LIABILITIES.	£	s.	d.	ASSETS.	£	s.	d.
Printing, etc.	14	1	7	Cash in Bank	91	17	0
Hire of Room	14	7	0	Money Invested in Building Societies	300	0	0
Salaries (2½ years)... ...	132	15	1	Arrears of Subscriptions ...	37	0	6
Stamps, Parcels, etc. ...	37	8	3				
Federated Institution of Mining Engineers—Call	22	3	2				
	220	15	1				
Balance of Assets over Liabilities	208	2	5				
	£428	17	6		£428	17	6

Mr. J. R. HAINES said that, seeing the financial position of the Institute, it would become a question whether the subscription of members should not be increased to £1 11s. 6d., as paid by members of other Federated Institutes or even £2 2s.; for if the past subscriptions had been paid on the former basis, it would have barely covered their disbursements.

Mr. T. M. FAVELL moved the adoption of the report, observing that if the Institute was short of money the subscriptions must be increased.

The CHAIRMAN said if they did that they might cause some members to resign.

Mr. T. E. STOREY, in seconding the adoption of the report, remarked that he thought the question of finances was one which might very well be left to the Council to decide.

Mr. J. R. HAINES said he did not think that they could carry on the Institute with smaller subscriptions than those paid by members of other Federated Institutes. During the 2½ years, since they had joined The Federated Institution of Mining Engineers, their financial affairs had been going wrong.

The report was then adopted.

Mr. E. B. WAIN having been unanimously elected President, then took the chair, and delivered his inaugural address, as follows :—

PRESIDENTIAL ADDRESS.

BY EDWARD B. WAIN.

I beg to thank you sincerely for the great honour that you have done me to-day in electing me as your President.

When I remember the list of able, distinguished, and experienced men who have previously held the chair, it is impossible for me not to feel that I have a difficult task before me if the dignity of the office is to be maintained; but I trust, and have no doubt, that I shall have the fullest support from the Council and the members generally, and I hope that with their assistance the interests of the Institute will not suffer at my hands.

It will be my constant endeavour to promote by every possible means in my power, the usefulness of the body of which I am proud to be a member, and to which I am deeply indebted, not only for the great confidence shown by my election, but also for so much valuable information and experience gained at the meetings and discussions in the past.

The task will be especially difficult for me in following so able a chairman as our late President. You will all know better than I can tell you with what marked ability and tact he has conducted the business of our meetings for the past two years, and I am sure you will agree with me that he has been an ideal chairman and one whose example I may safely follow.

It is getting every year more and more difficult to find original subject-matter for a Presidential Address; the voluminous *Transactions* of The Federated Institution of Mining Engineers appear to have dealt with almost every conceivable subject in connexion with coal-mining. You will pardon me, therefore, if I do not attempt to deal at length with any one special subject to-day, but offer a few remarks and opinions on some of the more important questions which are just now prominently before us as mining engineers.

And I propose first of all to speak of ourselves. As a Staffordshire man I am proud of the progress which our coal-field has made and is still making. Notwithstanding the exceptional difficulties under which coal-mining is carried on here, and the disadvantages from which we suffer in

the distance from the greater coal-consuming markets, it is satisfactory to note that we are able not only to hold our own, but even to compete successfully with other coal-producing districts which are much more favourably situated.

Few colliery districts in the kingdom have of late years shown more signs of vigour and progress than has our own, and I venture to say that there is not one which can show such marked improvement as we can during the last twenty years. The last published statistics show that during the past twelve years there has been an increase in the annual output of coal and ironstone from North Staffordshire of over 40 per cent.

Within my own recollection there is hardly a colliery plant in the coal-field which has not been remodelled and modernized during the period I have mentioned, and the advantage due to such improvements is clearly shown by the fact that the average output per person employed in North Staffordshire is now considerably higher than the average for the kingdom. The exact figures being: —Average per person employed in North Staffordshire, 302 tons; average for the kingdom, 257 tons per annum.

Much of the improvement of late years is due to concentration of works, and there are many typical instances in the district of the devolopment of extensive plants from small beginnings, such as mark the history of coal-mining in many of the older coal-fields. Where a few years ago the output of our collieries was raised from numerous scattered shafts, each yielding a small quantity, we have now much larger outputs raised from one or two pits. The advantage is obvious: each of the small plants required its own staff of mechanics, enginemen, firemen, etc.; much more efficient supervision and economical working is now possible, and there can be no doubt that whatever improvements have been made either in the plant or the general working of the collieries, the work done by the North Staffordshire Institute of Mining and Mechanical Engineers has largely contributed to bring about such result.

In one respect, however, we have very little on which to congratulate ourselves, and that is as regards the death-rate from accidents. Although there has been very considerable improvement in this respect of late years, we are in the unenviable position of having the third heaviest death-rate of any inspection district in the kingdom, there being only two districts (Yorkshire and South Wales) in which our figures are exceeded.

Of the thirteen inspection districts we stand eleventh on the list as regards the death-rate per 1,000 persons employed above and

belowground, but eighth as regards the death-rate per 1,000,000 tons raised. It is true that the death-rate has shown of late years a substantial reduction, and is now only 1·6 per thousand persons employed, but surely we must not be satisfied with this, and we must feel that we have still work to do. Certainly we have—and particularly in the highly-inclined measures on the west side of the coal-field—exceptional difficulties to contend with, but the greater difficulties must be met by greater effort; we must not be content until we have altered a state of things which is, and will always be whilst it remains, a reproach to our district. On our shoulders as mining engineers and colliery managers there rests a huge responsibility, the care of the interests of the colliery proprietors, and, above all, the care of many thousands of human lives.

The first care of every colliery manager must be, and, I believe is, the safety of the workmen employed under him; and if any improvement can be made in the conditions of work, or if any reasonable legislation is proposed which has for its object the preservation of the lives and limbs of our workmen, we must take care that no purely sentimental opposition on our part hinders such good work.

I am not arguing that any farther mining legislation is, or can be, beneficial unless it is guided by the most careful and experienced of our mining engineers, nor do I think that any farther legislation affecting our vocation is probable, except on one special point of which I propose to speak later.

We must all admit that the legislation of the past, although it has been in some measure weakened by the lack of technical and practical mining knowledge on the part of its promoters, has proved to be of real service, not only to the workmen but to the colliery owners. It is quite true that it does bear hardly, somewhat too hardly, on those of us who are engaged in the management of mines; but it is very rarely that we hear of the powers which are given to the authorities being exercised in a harsh or unreasonable manner.

With all their faults and apparent burdens we must admit that the Mines Acts have been beneficial, but I believe that the greatest improvements have been due to the efforts of the colliery managers and mining engineers of this country. They have generally anticipated and often supplemented legislation, and have by their forethought and energy done much more for the safety of their subordinates than any Act of Parliament, however carefully drawn and administered, could do.

And it is but natural that they should do so. There are no dangers or risks in underground operations which they are not called upon to

share; and if by any means they can contribute to the welfare and safety of their workmen, they and their employers directly and indirectly reap a share of the benefits.

Legislation and inspection have done much to make the occupation of the miner safer and healthier, but the real secret of the great improvement has been the untiring energy with which our profession has striven to improve the conditions of underground labour, and one result has been that work has been carried on more vigorously, and therefore more economically.

We have just cause to be proud of the results of our labours in the past, but there is still work to do, and so long as there is any improvement possible we must use our utmost effort to effect it. Just as medical and sanitary science untiringly works and studies to combat disease, so must we leave no stone unturned in our endeavour to clear our district of the reproach which the present death-rate brings.

Now, gentlemen, it may be thought that, as I have called attention to this point, I should also say something as to the means to be adopted to bring about a happier state of things, and in doing so I must first ask you to think for a moment of the causes to which the accidents, which we all so much deplore, are due.

Turning to our inspector's report for the past year, it is found that of the 41 fatal accidents which occurred in 1893 in this district, 1 only was from explosion, 18 were falls of roof and side, 6 in shafts, 7 miscellaneous underground, and 9 on the surface.

From this it will be seen that the largest proportion of the fatal accidents are caused by falls, and it is to this matter that we must give our special attention. Of the 32 fatal accidents underground, 18 or 56 per cent., were due to falls of roof and side, and of these 14 happened to men at working-faces, 3 to men repairing or enlarging roads, and 1 only whilst working or passing along the roads.

Falls of roof and side have for years past been the most fruitful source of fatal accidents, not only in North Staffordshire but in every inspection district of the kingdom. I have no hesitation in saying that 90 per cent. of such accidents are avoidable, and are distinctly due to breach of rules or neglect of common precautions, either on the part of the injured persons or of their fellow-workmen.

In their annual reports several of the Inspectors of Mines have from time to time called attention to this fact, and almost without exception have expressed the opinion that in every colliery timbering-rules should

be established, which should specify a distance that must not be exceeded in the fixing of timber, with a view to ensure the props being set in a regular and systematic manner.

Under the special rules of this district a clause to this effect has been inserted, and the manager of each colliery is required "to adopt a uniform system of timber-propping at stated distances in the face of work under his charge, or in any part of the mine which in his judgment requires it."

But we must not be content merely with establishing rules: they must be strictly carried out by all parties. Knowing as we do the disastrous results of carelessness and negligence on the part of our workmen, it is a most important part of our duty to see that the strictest discipline is maintained, and even at the risk of appearing to act harshly we must use all the means in our power to emphasize the importance of strict compliance with the Mines Act and the Special Rules.

The safety of every man employed is so entirely dependent on the care exercised by his fellow-workmen that it will be little short of criminal on our part if we allow the rules to be lightly regarded.

It is, too, of the highest importance that in the selection of our underground officials we should make choice of men who we know can fearlessly do their duty, men in whom we can place implicit confidence, and men who by their superior energy and ability have earned the respect of those who are placed in their charge.

With the spread of education we may with confidence look forward to greater care on the part of the workmen themselves, and it will be our duty to aid in every possible way any movement which has for its object the instruction of the working miners in the technicalities of the industry in which they are engaged.

In the mining classes established by the Staffordshire County Council we have an opportunity of helping forward such work, and the Council of this Institute has for some years past devoted much time and attention to this important matter. Just fifty years ago, in their report on the Haswell colliery accident, Messrs. Lyell and Faraday wrote: "We believe that if the education of the miners generally can be materially raised it will conduce to the security of the lives of the men and the perfecting of the art of mining, more effectually than any system of Parliamentary inspection which could be devised."

Here, then, are the three special points which I suggest should receive our most earnest consideration in our endeavours to promote the safety of those employed under us; firstly, rigid enforcement of discipline; secondly, careful selection of underground officials; and thirdly, the extension of

technical education; and in doing so I do not wish to imply that these, especially the two former, are matters which do not always receive the careful attention of every thoughtful manager, but rather to emphasize the fact that our district unfortunately compares unfavourably with others, and to ask you to review the position and see whether we have done all we can to mitigate the evil.

I know we have special difficulties, but those very difficulties call for special energy, and I hope that the day is not far distant when we shall point with pride to the fact that the conditions of underground labour in North Staffordshire have been so far improved as to place us on a much higher level as regards freedom from accident than at present, when compared with the other coal-fields of the kingdom.

And now, I will pass on to speak of another matter of considerable importance, perhaps the most important which is engaging the attention of the mining profession at the present time.

During the past year considerable advances have been made in our knowledge of the properties of coal-dust as an agent in originating and extending explosions in mines.

In the final report of the Coal-dust Commission, and in the details of Mr. Henry Hall's experiments, we have had much valuable information added to our previous knowledge of the subject. Whatever may have been the opinions and theories of the past, I think I am not overstating the case when I say that it is now conclusively proved that coal-dust itself is sufficient to cause violent and disastrous explosions when stirred up and ignited by the flame from a blown-out shot, even in mines where no trace of fire-damp can be detected with the most sensitive testing-apparatus.

It may be thought that the report of the Coal-dust Commission would have been of much more value if it had embodied the results of experiments specially conducted under circumstances corresponding as nearly as possible with the ordinary conditions of a mine.

But it is doubtful whether any experiments conducted for a specific purpose would have been convincing; as in making such experiments the experimenters too often start with certain fixed ideas and theories, and their observations of the results are often influenced by the bias of their preconceived ideas as to what should happen.

Before the publication of the Coal-dust Report, however, circumstances arose which were far more convincing than any number of experiments. I allude to the Camerton colliery accident. As this is the first recorded case of explosion in a mine free from fire-damp, and, therefore, marks a distinct point in the history of the coal-dust controversy, I would call attention to a few of the leading facts.

The explosion occurred in workings where fire-damp was unknown. To quote the words of Mr. J. S. Martin, "fire-damp is absolutely unknown as a fact or by rumour in any of the eight seams forming the Radstock series in any part of the coal-field. It is consequently unnecessary to say that there has never been any seen in this colliery, either before or since this explosion."

In support of this statement it is interesting to note that no safety-lamp could be obtained within 7 miles of the colliery when required for the purpose of exploration after the explosion.

After the explosion, stoppings were built so as to completely cut off all ventilation from the district affected, but a careful examination failed to find any trace of fire-damp when the workings were re-opened.

Notwithstanding the entire absence of fire-damp, an explosion occurred on November 14th last, two persons being killed, but the main roads of the colliery were more or less wrecked for a distance of 4,500 feet. An examination of the workings showed that, at the time of the accident, the two men who were killed had been engaged in blowing down the roof in a main incline, the explosive used being loose gunpowder.

There were indications that a shot had been fired with 12½ oz. of powder; and that this had only partially brought down the stone, owing to a break in the roof which had allowed the force of the explosive to escape. The flame given off had proved to be of sufficient intensity to ignite the coal-dust accumulated in the road, and to cause very extensive damage.

Mr. Donald Stuart, of Bristol, in his recently-published work on *Coal-dust as an Explosive Agent*, deals with the phenomena observed, and proves that this was a typical coal-dust explosion. Now, the fact that an explosion of great violence did occur in a colliery which had been worked with naked lights in perfect safety for over a century, in a district where fire-damp was absolutely unknown, and in seams from which the coal-dust had been submitted to severe test by Mr. Hall in his experiments and found to be apparently harmless, was of sufficiently startling nature to call special attention to the matter, and to convince every person, however sceptical, who would carefully weigh the facts, that coal-dust is a source of real danger, even in the entire absence of fire-damp.

Mr. Stuart, in his book just mentioned, brings out the theory, by no means improbable, that if certain conditions favourable to the initiation of a coal-dust explosion occur—that is to say, intense heat as from a blown-out shot and coal-dust in a fine state of division—fineness of

the particles is not a condition essential to the farther propagation of the force of the explosion. He assumes that a certain distillatory action is set up, and gives instances in the Camerton explosion where lumps of coal, several pounds in weight, were subjected to distillation by the heat generated.

If this be so, and if the heat generated by the initial ignition be sufficient to reduce the particles of coal to a gaseous form prior to their ignition, many of the phenomena noted in connexion with coal-dust explosions will be better understood.

However this may be, the danger of coal-dust is now well established, and there is no doubt that the Report of the Coal-dust Commission will be followed by farther legislation affecting our calling. It will be our duty to carefully watch any Bill which may be introduced to deal with the subject, but I am sure that none of us will offer opposition to any reasonable and practicable measure designed to remove what is admitted to be a serious danger to the lives of our underground workers.

Before I leave the question of explosions, I should like to draw attention to the very great improvement which has taken place in this respect.

During the year 1893, the total number of lives lost through explosions of fire-damp and coal-dust was 160 in the whole of the United Kingdom.

When we compare these figures with the terrible death-roll of 1866, when 1,484 lives were lost from the same causes, we see something of the improved conditions resulting from the advance in mining science and from the labour of such institutions as this. But even here, there is still room for improvement. If we take the list of fatal explosions for 1893, we find that 154 of the lives were lost in consequence of the use of naked lights in mines where gas was only occasionally met with, and 4 from explosions of coal-dust ignited by blown-out gunpowder shots. Only 2 occurred in mines where safety-lamps were used, and these were due to deliberate breach of the law by a workman.

In face of these figures, we can hardly say that those persons who argue in favour of the entire abolition of naked lights in coal-mines have not some substantial grounds for doing so, and it seems probable that we may have to face the question before long. Safety-lamps, like most other mining appliances, have been greatly improved of late years, and the old argument that the inferior light of the lamp as compared with naked lights tended to increase the accidents from falls of roof has proved to be fallacious. Moreover, the notion that the light of the safety-lamp was more injurious to the eyes than that of a naked light has been found to

be erroneous, as men working in naked-light pits have been proved to be equally liable to that peculiar disease of the eye known as miner's nystagmus, which was at first supposed to be due to working with an inferior light, but which has been found to be a muscular disease due to the strained position in which some men place themselves when working.

It is difficult to find any grounds on which to defend the use of naked lights in any mine where there is the remotest probability of fire-damp being met with, and the experience of last year seems to point to the fact that greater restriction in the use of open lights is necessary.

Perhaps the experience of a single year is not sufficient to draw general conclusions from, but if we go farther and examine the records of the past twenty years we find that over 75 per cent. of the deaths from explosions are directly traceable either to the use of naked lights or gunpowder.

I have called attention to these matters, because it seems very probable that in future legislation farther restrictions will be placed on the use of open lights and of gunpowder, and it will be our duty to anticipate the alterations which may be made, so that any amendment of the law will not seriously interfere with our plans and methods of working.

It is not probable, however, that the entire abolition of the use of gunpowder will be required, although it is probable that the restrictions placed on its use will be such as to prevent it being so extensively employed in coal-mines as at present.

Many mining operations would be attended with great difficulty and serious expense without the use of some explosive, and it is doubtful whether some seams could be worked at all at a profit without blasting.

We have in several of the new "flameless" explosives, however, means by which the use of gunpowder with its attendant dangers may be dispensed with in dry and dusty mines. Although there is not yet in the market any high explosive which will take the place of powder either as regards efficiency or economy, there are several which run it very close, and there is no doubt that to meet the growing demand for a safe and efficient substitute the manufacturers of mining explosives will before long give us even better results than at present. What we require is an explosive with the flameless and other good qualities of the many "ites," but free from their shattering action, and the introduction of such a substance will be the means of speedily putting an end to the use of gunpowder in coal-mines.

So far I have spoken only of what must always be the first duty of every colliery official—that is, care for the safety of the persons employed under him; but we cannot forget that we have also grave responsibilities

of another kind. On our efforts and action depend the success or failure of the most important of British industries, with its millions of invested capital, and the circumstances of the times are such that it is only by severe economy and strenuous effort on our part that a fair return can be made on the money invested. Keen competition and a high rate of wages have reduced the margin between working cost and price realized to a very narrow limit, and the closest attention to detail is necessary in all the items of expenditure.

Under such circumstances as these, it may be thought that I have perhaps laid undue stress on the questions already spoken of, but if I have done so it is because I believe that the more we can contribute to the safety and health of our workers the better results we shall obtain from their labour.

The legislation of the past has been to some extent burdensome, perhaps more burdensome than those of us who have grown up under the Mines Acts can really appreciate, but I venture to say that the very fact that the restrictions imposed by law have to some extent added to the cost of production has turned the attention of mining engineers to the necessity for improved appliances and methods of working, and the net result has been that their effort and action has been the means of more than counterbalancing any increased expenditure directly due to legislative restriction.

In speaking of the effects of legislation I should like to mention the question of employers' liability as it affects us, and I consider that the working of the Act has done nothing at all towards bringing about the great improvement as regards safety.

I believe that colliery proprietors and managers have a far higher motive in taking every possible precaution for the safety of their employees than the mere avoidance of pecuniary compensation, and that whatever action they have taken which has tended to make the occupation of the miner safer and healthier has been due to a genuine interest in the welfare of their workmen and not to any sordid and selfish motive.

Placed as we are between employer and employed, all labour questions are naturally of grave interest to us. The question of the hours of labour is of peculiar interest, but to speak at the present time against the Miners' Eight Hours Bill would seem almost like flogging a dead horse, although no doubt we have not heard the last of the matter.

In conclusion, to those of you, my seniors, to whose efforts are due the great improvements in mining science in the past, I have little more to say except to tender to you my hearty thanks not only for the splendid

example of perseverance and progress which you have set me and the other younger members of this Institute, but also for many acts of kindly encouragement and assistance.

And to you, my younger colleagues, I would say, remember in whatever difficulties you are placed, you will have few more difficult problems to solve than have been met with and overcome in the past, and in dealing with them you have opportunities which many of our predecessors could hardly have dreamt of in their earlier days.

You have at your command greater educational facilities, the wonders of modern science are before you, ready to be applied to the needs of your daily work, and you have, in such Institutions as this, means of obtaining special and widespread knowledge of matters peculiar to our profession based on the experience of others, in records of difficulties overcome and successes achieved in the working out of practical details in the manifold branches of mining work.

You will meet with difficulties, but they will have to be faced and overcome. Our work lies in the future and in an age of progress. In an age of progress, we must go forward with the determination to raise higher and higher the standard of excellence in the science of mining. We may occasionally meet with discouragement and failure, but these should only nerve us for greater effort for the work we have before us.

In our work we must be thorough, no details must be too trifling to be carefully considered, and above all we must remember that in mining, as in every other branch of industry, work carefully done will always bring its own beneficial results.

If I may in a few closing words offer you advice, I will say, carefully consider the circumstance of your position, and having once decided on a line of action proceed without hesitation and with confidence in yourselves. Remember, however, that the experience of others, even those in inferior position, is always worthy of consideration, and should be taken into account in arriving at any decision. Be firm in your dealings with those placed under you, but remember that you can be firm without harshness. Courtesy costs nothing, and although you may have to use the iron hand, it will have as firm a grip if covered by the velvet glove.

The future of a great profession lies in our hands, and our action must be such that, when the history of mining engineering in the closing years of the nineteenth century comes to be written, the world may see that the labours of our Mining Institutes have not been in vain, but have been the means of making a difficult and dangerous industry safer for those employed and more profitable to the employers.

Mr. W. N. ATKINSON moved a vote of thanks to Mr. Wain for his admirable address, which was well worthy their best consideration.

Mr. T. E. STOREY, in seconding the proposition, said it was a most valuable address, dealing with many important points connected with the mining industry, and a careful perusal of it would be of great advantage to all the members.

The resolution was carried with applause.

Mr. WAIN briefly acknowledged the vote, and proposed a vote of thanks to the retiring president for his valuable services.

This was seconded by Mr. JAMES HEATH, M.P., and carried with acclamation.

ELECTION OF OFFICERS.

The scrutineers (Mr. J. B. ANLEY and Mr. A. S. HEATH) reported the following elections :—

PRESIDENT.

Mr. EDWARD B. WAIN.

VICE-PRESIDENTS.

Mr. W. N. ATKINSON. | Col. JOHN STRICK. | Mr. JOEL SETTLE.

TREASURER.

Mr. HUGH R. MAKEPEACE.

SECRETARY.

Mr. J. RICHARD HAINES.

COUNCIL.

Mr. THOMAS ASHWORTH.	Mr. J. NEWTON.
Mr. JAMES C. CADMAN.	Mr. J. J. PREST.
Mr. T. M. FAVELL.	Mr. F. SILVESTER.
Mr. JOHN HEATH.	Mr. T. E. STOREY.
Mr. H. R. MAKEPEACE.	Mr. WM. STATHAM.
Mr. G. A. MITCHESON.	Mr. B. WOODWORTH.

ALTERATION OF RULES.

Mr. HAINES proposed that Rule 8 be altered to read as follows :—
"That the Retiring President be an *ex-officio* Vice-President for the year following his year of office as President; and that every Past-President be an *ex-officio* member of the Council as long as he continues a member of the Institute."

Mr. J. NEWTON seconded the proposition, which was adopted.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
NOVEMBER 12TH, 1894.

MR. E. B. WAIN, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentleman, having been previously nominated, was elected :—

MEMBER—

MR. GEO. HERBERT ROBINSON, Mining Engineer, Birchenwood Colliery Company, Limited, Kidsgrove, Staffordshire.

Mr. J. J. PREST read the following paper on "Colliery Cost-sheets":—

COLLIERY COST-SHEETS.

BY J. J. PREST.

The writer has brought the subject of cost-keeping before the Institute, not with the view of giving information, but chiefly with the object of obtaining it. There are greater difficulties in carrying out an elaborate system of cost-keeping in North Staffordshire than in almost any other district with which the writer has any acquaintance, owing, to some extent, to the mode of working, and partly also to the fact that in many instances ironstone and coal are drawn, not only from the same shaft, but from the same seam. It is hoped, therefore, that the discussion may be the means of placing on record the simplest and best means of carrying out what cannot but be regarded as an important feature of colliery management.

The question may be conveniently discussed under the heads of:—(1) Labour cost accounts; (2) general cost accounts; and (3) summary of costs.

1. LABOUR COST ACCOUNTS.

The forms exhibited by the writer have been designed to illustrate his idea of suitable "labour cost-sheets" where many of the conditions exist that have been previously mentioned. It will be generally admitted that some system of ascertaining in detail the cost of labour per ton of mineral produced, or paid for, is of the first importance to a manager, and it is possible to go farther and say that unless these accounts are carefully and minutely kept from pay to pay, the management of any mining enterprise is not likely to be so economical or successful as would otherwise be the case.

In the forms exhibited, the cost of working each particular seam in the pit is obtained, by first classifying the labour under as many distinct heads as may be thought desirable, and then charging the amounts direct, where possible, to the particular seam; or, where this cannot be done, as in the items of overmen, hooking, etc., dividing the amounts in the same ratio as the relative tons produced from the different seams, and charging each seam accordingly. There is no difficulty in carrying out this practice when once the system has become fairly established, although

some little ingenuity is required at times to fairly apportion the charges week by week as between black-band coals and ironstone, clay-bands of ironstone and coals free from ironstone, when all these are being worked from one and the same pit.

Labour costs are very generally based on the tons produced, or paid for, at the pit, and are therefore only useful as a means of comparison with the labour costs of previous pays. These costs should be in the hands of every colliery manager at the time appointed for examining the pay-sheets with the various subordinate officials, so as to enable him the better to check the expenditure of heads of departments, in no matter what direction.

It was a common custom in some districts a few years ago for the subordinate heads of departments to make out their own wages and cost-sheets. The under-manager or overman would make out the underground wages-sheets; the bank-inspector that of the screenmen, banksmen, labourers, etc.; and the engineer would make out the wages-sheets for the mechanics. Whatever drawbacks this system had, and there are several that could be mentioned, it certainly had the advantage of solidly impressing on the memory of these officials the cost per ton of each class of labour working under his immediate authority, and to that extent was conducive to care and economy in the administration of their departments, under all conditions of trade. This system has during recent years become more or less obsolete, owing possibly to the greatly increased responsibility resting on all persons employed in the management of mines, the services of such persons being generally thought to be best utilized in active superintendence of their particular departments, whilst the work of making out wages-sheets and costs-sheets is now generally performed by clerks.

The statistical information shown at the bottom of the form exhibited is abstracted from each pay-sheet, and forms a very useful record for reference in many instances that will readily occur to the minds of colliery managers.

2. General Cost Accounts.

In addition to the ordinary labour costs, it is necessary at certain fixed intervals, say, every two or four weeks, to have a more accurate statement prepared showing the absolute cost of production over this period, as it would be impracticable to prepare a balance-sheet to show the results of working for each month. These cost-sheets partake more of the nature of a profit-and-loss account, and show the results of working to date within prescribed limits.

This cost-sheet will in all probability be made out on the tons accounted for or disposed of, and these will in nearly all cases show a greater or less quantity (more often the latter) than the tons paid for at the pit, this discrepancy arising from refuse and dirt picked out of coal, allowance to customers, variation in tare, weights of trucks, etc., all adding to the probability that a smaller number of tons will be accounted for than the colliers are paid for getting; and in such cases the cost will be proportionately increased all round.

In some instances this cost is worked out on the production; that is, the coal paid for at the pit, and in others on the sales only; but the writer submits that the most accurate system is to work out this statement entirely on the tons accounted for.

All fuel consumed on the works is charged for as materials, at market prices for similar classes of coal; whilst coal put to stock on the ground is valued at much less than current market prices, on account of the deterioration which naturally takes place; coal in waggons and on the pit-bank may or may not be taken into consideration in the general cost-sheet. The writer's experience is adverse to its inclusion, as the quantity of coal paid for, and not yet accounted for in this direction, usually balances itself month by month.

Materials received during the month may be charged direct from the invoices, or charged to a suspense account, and a certain amount debited to the pit, month by month, until the whole sum has been wiped off, so as to render comparison between the cost per ton over a definite period more uniform and reliable.

Rents, rates, and taxes, as well as other sundry items difficult to obtain accurately, may be estimated at a certain rate per ton to cover probable charges, and rectified, if necessary, at the end of each half-year; in this way it is not a very difficult matter to ascertain the absolute cost of the coal or ironstone accounted for, within a small decimal of a penny per ton, month by month, or even for a shorter period, on the day following the prescribed term.

The average selling-price realized is also a matter of prime importance, and should be got out by the clerk in charge of the sales department on the day following the period for ascertaining the general costs. The sales-sheet should also show clearly the average price obtained for all classes and qualities of coal from each pit, and as far as possible, also, for each market, as well as the quantity and value of coal put to stock, consumed on the works, etc.

The forms for general cost-sheets, as well as for labour costs and summary, have been arranged for this paper, and may be taken for what they are worth.

The writer may perhaps be permitted at this point to notice the advantage of the slide-rule to colliery managers in calculating costs, as well as for many other calculations involving tedious arithmetical problems. The cost per ton for any number of items may be ascertained with the slide-rule as rapidly as they can be written down, when once a person has become familiar with its use.

3. Summary of Costs.

Where several collieries are being worked by the same firm, the net results are very conveniently grouped together in one general summary showing the gross working-cost and average selling-prices obtained for each class of fuel from each pit, as well as the profit or loss on the working of the whole concern over the period embraced by the general cost-sheet.

Mr. Joel Settle said that in these depressed times it behoved every colliery manager to look carefully to the working cost. Mr. Prest suggested an extraordinarily detailed sheet, but it was very essential that every item should come under its own classification. He knew that cost-sheets were kept in the manner described, because he had had an opportunity of seeing them, and by that system they could see week by week what the detailed costs were. He did not go into all such details himself, but by Mr. Prest's system they could see their position week by week.

Mr. J. R. Wain said there was no doubt that an accurate statement of the costs of wages, and of the timbering and stalls, week by week, or even fortnightly or monthly, was a valuable assistance to a colliery manager.

Mr. H. M. Lynam observed that he had often heard people giving the working costs of getting minerals, and those costs had sometimes been so extremely low that he had wondered what had been included in the calculation. He suggested that if everything was dealt with by others as by Mr. Prest the figures would not be so low as he had heard them stated. When Mr. Prest came to the Shelton collieries, they already had somewhat elaborate cost-sheets, and when he was anxious to introduce the system now described, he (Mr. Lynam) thought it would prove cumbrous and not workable, but the clerks soon got into the way of writing up the sheets, so that there was no difficulty about the matter. The result was invaluable to him (Mr. Lynam) as general manager, and he was sure it must be to Mr. Prest, as a practical colliery manager.

Mr. J. R. WAIN said there was the important question of depreciation —a large question deserving a paper by itself. What should be allowed weekly for depreciation to show the actual weekly costs? Perhaps some member would take up this point when the paper was farther discussed.

Mr. W. BAILES referred to an instance in which depreciation of plant was considered to be covered by the cost of repairs and renewals being charged direct to revenue account; if the renewal was a heavy item, the amount was put to a suspense account, and spread over a longer period of time. A depreciation account was kept in the form of a tonnage rate charged against every ton of coal drawn; this depreciation fund was intended to redeem the capital in a given number of years. A very careful account was kept of the tonnage drawn, and all the coal used on the works was charged to the different departments and credited to the sales account. A reliable detailed weekly cost-sheet of wages, salaries, stores, royalties, rents, rates, taxes, incidental and miscellaneous expenses was kept, together with a monthly sheet, showing the average cost per ton, and the average selling prices of the various classes of coal, etc.

The PRESIDENT said that Mr. Prest had gone into detail, and he thought it was just possible in going into such small details, that Mr. Prest might have unduly weighted the matter. Two items in the form were overmen and firemen, and they might be classed together. Jigging, tramming, and driving were given as three items; they might be included in one. Although it was useful to have these details, he did not think, for general information, such as they looked for in cost-sheets, that such details were necessary. He (the President) was under the impression that at a particular colliery with which he was connected they had an elaborate system of cost-sheets, but they had nothing like the minute detail suggested by Mr. Prest. There was one form which engineers could understand better than figures, the graphic form, as in a barometer-chart, to which Mr. Prest had not referred.

Mr. SETTLE moved a vote of thanks to Mr. Prest for his paper, which was seconded by Mr. J. R. WAIN, and passed unanimously.

Mr. PREST said that his principal object in introducing the subject of his paper to their notice was to obtain information as to the general practice of cost-keeping in that district, where there was a great many obstacles to be overcome before a good system could be established. Some of the members seemed to think there was too much detail in his system, but his experience of colliery management in this direction was that there could not be too much detail if leakages were to be prevented, and to do this successfully, the cost of every item must be known. The

labour involved in getting out these particulars was very small if properly organized, and he could assure them that the cost was well spent. The President had alluded to the graphic method of showing results; this was no doubt an excellent plan for illustrating work of any description, but he submitted that it would be necessary, first, to obtain all the details he had brought before them, to show graphically the variation in costs from pay to pay, and that this diagram would be adding to the labour involved in cost-keeping without any corresponding return. The system described was not original, and he should be glad to learn what had been done by other members working under similar conditions.

Mr. Hassam read the following paper on "Gob-fires in Longwall Workings, with Special Reference to the Yard Seam":—

GOB-FIRES IN LONGWALL WORKINGS, WITH SPECIAL REFERENCE TO THE YARD SEAM.

By ARTHUR HASSAM.

Of all the dangers which have to be encountered in coal-mining there is perhaps none whose approach is more subtle and insidious than that of spontaneous heating and firing of the goaves. So much has been said and written upon this subject, and the disastrous results attendant upon gob-fires are so widely known, that the writer need not dwell upon its importance, nor apologize for bringing it forward once more.

In this district, gob-fires are unfortunately of very common occurrence, and the deep gravity of the question is being accentuated, time after time, by waste of coal, destruction of property, and deplorable loss of life.

The physical conditions of mining in some parts of North Staffordshire, are of such a character as to utterly preclude getting to the seat of a gob-fire, and also to render the building-off of the affected part of the mine an operation of much difficulty, and often of great danger. Some time ago Mr. Joel Settle read a very able and interesting paper before The Federated Institution of Mining Engineers, dealing with fires in mines of this class.*

On the present occasion, therefore, the writer proposes confining his remarks to fires in seams of moderate inclination and thickness, worked on the longwall system; and having experienced much difficulty during the last three or four years, in dealing with some which have occurred in the yard seam at Oldfield colliery, Fenton, he will briefly refer to this colliery before proceeding to more general observations.

The yard seam was found at a depth of 1,870 feet from the surface, and was opened out in 1887. A section of the seam through the working-face is shown in Fig. 1 (Plate XVIII.). Two beds of coal are worked, the upper one being about 2 feet 3 inches, and the lower one 4 feet 6 inches thick. Between the two beds there runs a band of highly

* *Trans.*, vol. v., page 10.

carbonaceous culm or hussle 10 inches thick. This is very flaky and oily, and the holing is easily made in it. The inclination of the strata is about 1 in 5, rising towards the east.

The system of working is pure longwall, with levels approximating to the line of strike, with self-acting inclines or jigs at right angles thereto. The drift-jigs are put in at intervals of 150 feet, and there is generally a carving or step between two drifts.

Packs are built 15 feet wide on each side of the levels and jigs, and 12 feet thick alongside a carving. The intermediate packs are 9 feet wide, and there is usually one on each side of a drift. The wastes are generally 15 or 18 feet in width. The upper seam of coal is only gotten in the wastes and roads, and is left over the packs. Chocks, 3 feet square, are built at the road-ends as the faces advance, and until quite recently the custom was to leave these as permanent supports. It was found, however, that the wood fired in several instances where it was in contact with the packing-material, and it was ultimately decided to take them out wherever practicable.

The ventilating-current sweeps the faces in two splits, one from the north and the other from the south extremities, which unite at an intermediate point and pass into the return airway.

Not long after the seam was opened, signs of gob-heating were observed, and as early as December, 1888, a portion of the north faces had to be built-off. Since then many heatings and fires have been dealt with. Some were successfully checked while in an incipient stage; others have been dug out; while others again have been shut-off with more or less difficulty. Plans are shown which the writer will briefly describe, illustrating two districts where more than ordinary trouble was experienced.

Fig. 2 (Plate XVIII.) is a plan of parts of Nos. 2 and 3 south districts. On August 14th, 1893, gob-stink and vapour were perceived arising from *A*, and the wall and pack shown at the top of the drift were at once built. Six days afterwards fire was found at *C*; this fire was dug out, and a wall was built along the front, with sand backing.

On August 24th, 1893, fire was discovered at *B*. The fire was fortunately dug out,* and no farther harm resulted at that time. It did, however, revive some days later, and was not really conquered, when on September 11th, 1893, smoke was found coming from *D* and about the

* The writer may mention incidentally that while the men were engaged upon this highly important piece of work, a mob of strikers and their associates came to the colliery, compelled the men to come out of the pit, and seriously assaulted them when they arrived at the surface.

same time from *E*. At both these places the points of ignition safely accessible, and proceedings were taken to build them off. shut-off without serious difficulty, and *D* was closed in by s placed at the points *S 3*, *S 4*, and *S 5*. The management were de keeping the level open beyond *S 5*, so as to open out another airwa the fire at *E* should become more serious. The stoppings to *D* w pleted early on September 13th, and six hours later an e happened which blew out the stoppings at *S 3* and *S 5*. The m unable to rebuild these stoppings, and others were built at *S 1*, *S 6*. As sufficient bricks and mortar were not at hand, the stop *S 6* was built of bricks with sand between, and convex towards th the fire, and at *S 1* and *S 2* the packs were merely built up to and rammed tight. These stoppings were found to be effective, a ultimately strengthened with bricks and mortar, and sand and dirt- as shown in Fig. 2.

Towards the end of 1893 much difficulty was experienced in th district, which has always been the most troublesome part of (Fig. 3, Plate XVIII.). On September 30th, 1893, a fire was discov the pack at *C*, and another, later on the same day, at *B*. The fir was easily dug out, but the one at *C* could not be got at, exce incurring serious risk and danger. A brick-and-mortar wall, 2 feet well backed with sand, was therefore built around the smoking pack and a heading commenced to be driven in the solid coal above, s stoppings *S 1*, *S 2*, and *S 3* could be built and the affected part shu

This work was not completed before fire broke out at *E*. The was too bad to remove this fire, and an archway of brickwork 18 i thick was built along the level adjacent to the fire, well rammed o sides with sand. The arching was strengthened by heavy iron curved to suit the archway, and fixed at intervals of 3 feet. The wa on the upper side, with good sand backing, was joined around the p walls to the wall at *C*, and also continued to No. 12 jig, at the botto which another archway was built, as the roof was much broken, and and gob-stink came out of the fissures.

Another fire took place at *F* on October 22nd, 1893, and stopp *S 5*, *S 6*, *S 7*, *S 8*, *S 9*, and *S 10* were put in; while a brick wall, inches thick, backed with sand, was run along the low side from the a way at *E* to a point beyond No. 5 stopping. These measures were fo to have the desired effect, although the stink and heat died away slowly. For many weeks it was impossible to bear one's hand upon brickwork at *E*, but the place finally cooled down. About the same t

a fire occurred at A, which was dealt with, without much trouble by digging-out—building the brick wall, and leaving a pillar of coal near the fault, as shown in Fig. 3.

As regards the origin of these spontaneous ignitions in the goaves of coal-mines, there seems to be no doubt that the exciting cause is absorption of the oxygen of the air, by hydro-carbonaceous substances, in a more or less fine state of division. In this particular colliery, it would appear that the most readily oxidizable substance is the holing-dirt intermixed with a small proportion of slack—more especially if from places on, or contiguous to, a fault. Fires and faults have been found associated so frequently, that special attention is now given to the latter when met with.

A number of fires have been found to have first ignited at timber buried in the packs. On two occasions the discovery was made that drift props had been improperly left standing in the packs, and that probably in consequence of the increased temperature, produced by the oxidation of the surrounding packing, the wood had ignited, for it has a much lower ignition-point than the exciting substance. Several times also the inner sides of square wood-chocks have been found on fire, and this led, as before stated, to their withdrawal as far as possible.

There is much difference of opinion as to the amount of air which should circulate in mines subject to spontaneous heating. Some advocate ventilating the goaves, arguing that such an operation would cool them; others suggest a very sparing use of the ventilating-current, just sufficient, indeed, to keep the pit clear of gas; and also to exclude the air as far as practicable from the goaves.

In deep and gaseous mines, which are generally of a dry and dusty character, and of a somewhat high temperature, a margin of air high above the line of mere necessity, ought always to be in circulation, if contingencies have to be safely met, and the men to work in moderate comfort. But admitting oxygen to be the primary exciting agent in spontaneous heating, it is obvious that the air-current should be strictly confined to useful courses. The airways should have as large a sectional area as possible, and the velocity of the current thus kept low, so that the air should not be driving into the pack-walls, as this undoubtedly constitutes a very important factor in generating gob-fires.

In coal-mines of this character, perhaps the most important element in working them is proper and efficient packing. The packs should be very well built with good stone-walls, and the interiors rammed tight with close-lying material, so that they may be practically impervious to the air. (If the seams are thick, and proper packing material is not

procurable, it is courting disaster to work them on the longwall system.) The packs should be built square up to within a reasonable distance of the face, good stones being used for the cross-walls at each shifting. Care should, however, be taken that they are not sufficiently near to check the ventilation, as the tendency would then be to drag the air through the pack, with probable resultant heating.

All timber which can be safely gotten, should be drawn from the back-workings—especially out of the pack-walls. The experiences in the yard seam have been rather peculiar in this respect. The fires have, without exception, occurred in the solid pack-walls, adjacent to an airway, and generally near the floor. But in no single instance has a fire ever been found, either in the top coal left over the packs, or in immediate contact with it. No doubt exists in the writer's mind that there is less liability to fires of this class if all timber is withdrawn from the packs. In several instances the seat of the fire has been burning timber, and, as before mentioned, the writer can only attribute this to the wood having a lower ignition point than the packing; and to draw from it the conclusion: that if the timber had not been thus buried the material might probably have begun to cool down again before the point of ignition was reached.

It is also desirable that the carvings should be short, and the faces moved as rapidly as possible, so that the current should be continually traversing new ground. All slack should be sent out of the pit, because even if the slack will not *per se* fire, it undoubtedly intensifies the evil with a heating hussle.

A point in working coal-mines of this class, to which too much importance cannot be attached, is not to confine the return airway to the faces only. There ought ever to be an auxiliary way quite independent of the face-road, whenever and wherever possible. This may even be a desideratum as a precaution against falls and obstructions at the faces, but its utility in cases of fires cannot be over-estimated. On many occasions it would be a comparatively easy matter to build the packs up to the face, or fill up a carving and check an incipient, or even a developed gob-fire, if there were another road for the return air to travel; but where there is no other return, the situation may sometimes become very critical.

The length of face ventilated by one air-split should not be too great. It is very undesirable that if a small, or, indeed, any kind of fire happens, and is shut off, that 1,000 or 2,000 feet of working-face should be fouled by the gob-stink which will inevitably creep out of packs and fissures for some weeks or months afterwards.

A useful precaution is to use fireproof brattice-cloth only. On one occasion which the writer remembers, flames were discovered coming out of a pack on the side of a jig within six feet of a heavy brattice of several folds of tarred cloth, in a dry and dusty road, heavily timbered. Had this cloth caught fire the results might have been disastrous.

Sometimes where packs have had a tendency to heat, they have been checked by ripping the roof down, and burying them under foot, occasionally putting a layer of sand on the top.

Gob-fires generally break out very suddenly, the first sign being a heavy white smoke coming out of the pack-wall. If the roof be fairly good the fire can usually be dug out. Water is conveyed to the place, before breaking into the pack-wall, and as the fire is found, is very sparingly used to keep the flames down. A rather copious use of water is undesirable on account of the steam produced. It is much better to send the hot material out of the mine. Afterwards the place is carefully watched for several days and allowed to cool down, and then filled up again, and faced across the front with a brick-and-mortar wall, backed with sand. Sometimes it is found sufficient to rebuild the pack, and plaster the front with mortar.

If, however, the fire occurs under a bad and broken roof the chances of successfully removing it are very remote, and it has to be built off. If this can only be done by shutting-off the district affected, many circumstances have to be considered in fixing the choice of the sites for stoppings. The places should be as sound and small as possible, and, of course, not a foot more space should be inside than is absolutely necessary, as it would appear to be almost certain that an explosion will happen behind the stoppings sooner or later.

Rather a large area was built-off in the yard seam in 1891, and everything was quiet for twenty-four hours. An explosion then occurred, but the stoppings had been strengthened and withstood the shock. Other explosions took place at intervals during the night, but they gradually got weaker, and finally ceased.

The writer has always found that ordinary pack-walls form quite sufficient buttresses to the stoppings, and has also effectively shut off districts by simply filling the carvings with small rubbish, ultimately facing them with a brick-and-mortar wall.

In building up a space in which an explosion may be reasonably expected to occur, and where it is not thought safe to stay and strengthen the brick stoppings with stowing, it is advisable that the walls should be built convex on the side next to the fire, and strengthened on both sides

by timber sprags thoroughly well wedged up, as the stoppings may be subjected to an explosive force before the mortar has had time to set. There is reason to believe that if the stoppings at *S 3* and *S 5* (shown on Fig. 2, Plate XVIII.) had been thus spragged, they would not have been blown out.

After the work has been made as secure as possible and the district sealed off, all the workmen should be withdrawn from the pit for a period of time depending upon the position of the fire, the amount of space enclosed, and the rapidity with which gas is likely to be produced. As already noticed, in one case in the yard seam it was twenty-four hours before the first explosion happened, while in another case it was only six hours. The difference doubtless was due to the difference in the amount of open space which became filled with gas before ignition could take place. Upon entering the mine, if all is right, very active measures should be taken for strengthening the stoppings, and this should be thoroughly done before the ordinary work of the mine is resumed.

Coal-mines of this class must inevitably be a source of the most constant and deepest anxiety to the owner and manager, but the dangers and difficulties can undoubtedly be greatly minimized in proportion as they are more fully understood; and if precautionary measures, arising out of the knowledge gained from past experience, be adopted and strictly carried out.

The writer does not contend that the *modus operandi* which has proved eminently successful with the fires in the yard seam would be equally applicable everywhere in the district, neither does he put it forward as a new thing. Certain points have, however, been brought so prominently before his notice in connexion with this work, and the whole subject is of such vast importance to the district, that he thought a useful discussion might be initiated, if the question were brought before the Institute.

Gob-fire is undoubtedly the one element which makes mining in the North Staffordshire district so highly dangerous and precarious. The physical properties of gas and water are thoroughly understood, and we know where to look for, and also how safely to deal with them when found; but we do not yet know the exact why, where, and when of a gob-fire, and we cannot foretell the end of one? They frequently break out in the most unexpected places, sometimes accessible, sometimes inaccessible, and always entail more or less expense and danger. It is only by individual practice and experience being made public, by open discussions, that a general and useful knowledge of the subject is likely to be

arrived at, and the writer's object in bringing the matter before the members will be served, if this paper in any way leads up to, and contributes to that very desirable end.

The President remarked that Mr. Hassam had dealt with an important subject in a very practical manner. They were all more or less familiar with the theory of gob-fires, and they wanted to know how to deal with them when they did happen.

Mr. W. N. Atkinson said that Mr. Hassam's paper was very valuable, on account of the practical details which it contained. One feature that struck him was, it was stated that all the gob-fires described had taken place in the packs. Mr. Hassam did not give them any reason for that, except that they might have been due to timber left in the packs. One point that Mr. Hassam laid stress upon was of the utmost importance —namely, the desirability of strengthening the stoppings as soon as possible after they were put in—as soon as it could be done with safety. In some cases the risk was too great to allow of its being proceeded with at once, owing to the position of the seat of the fire.

Mr. Prest said that he should like to know if they cut up to the solid strata in building the brick-wall along the level.

Mr. Hassam said that they simply built up to the roof.

Mr. Prest considered that many of the difficulties and dangers incidental to the working of coal-seams, subject to spontaneous ignition, might be more successfully dealt with, if they were opened out and worked on the pillar and wall, or by longwall working homewards, instead of by working ordinary outward longwall as was generally the case, added to a well arranged system of internal barriers. A fire taking place in any one of these districts could then be dealt with, by simply building off the pair of drifts giving access to the workings in the district with some certainty of success, and with a minimum amount of loss and danger.

Mr. G. A. Mitcheson said that he had been very much interested in Mr. Hassam's paper respecting the gob-fires in the yard seam. He was surprised at one thing which Mr. Hassam said, and that was that the holing-dirt was the chief cause of the gob-fires. Personally, he should not have thought that the holing-dirt itself was liable to spontaneous ignition. He should have been more inclined to think that the fire was due to the small slack and coal, and it was a striking fact that these fires had only been found in the packs when, in working the coal, the top

coal over the packs was left up. He suggested whether the coal left over the packs in the course of the working had not something to do with the origin of fires. It was a peculiar feature of the yard seam that at one colliery there was considerable trouble with gob-fires, whilst at an adjoining colliery, where the same seam was worked, there had been no trouble. When they commenced working a seam like the yard seam, which was liable to spontaneous combustion, it should be treated from the first as if it was going to fire. He knew a case in which a coal-seam, liable to gob-fire, was recovered, but because there was no sign of spontaneous combustion during the first year or two of working, some of the officials said that at that particular colliery the nature of the coal-seam had changed, and that there was no fear of any gob-fire. However, after a fair amount of goaf had been left behind, trouble began, and it was found out that the coal-seam was just as liable to spontaneous combustion there as it had been at other places. He thought something more might be done with these coal-seams, by going out to the far end and working the longwall towards the shaft, leaving the goaf behind. Where they had a coal-seam like the yard seam, overlaid by a variable thickness of somewhat tender metals, above that a strong rock, a breasting might be driven, say 60 feet wide, to the far end, and drifting commenced at the far end. There was another advantage in working a coal-seam on this plan, and that was that the cost of road repairs would be very much less than in cases where all the coal was taken out. There was another way in which such a seam might be worked: on the dip, and the goaf filled with water, but that would be difficult to do at many places.

Mr. JOEL SETTLE observed that the subject of spontaneous combustion was most important in that district. He was of opinion that North Staffordshire would be the richest coal-field in England, but for the treacherous and dangerous fires which took place from time to time. He quite agreed with Mr. Hassam as to the point of not ventilating the gobs, but of taking the air from them. He remembered when he read a paper on gob-fires,* there were many who thought that the air ought to be passed through the goaves; but there was no doubt if they got a fire in this district, they must take the air off the goaf as quickly as possible. The important suggestion of Mr. Mitcheson was not only applicable to collieries subjected to spontaneous combustion, but practically to all mines —that was, going to the far end before working the coal. The advantage would be, they would leave the goaf behind, and they could shut it off if

* *Trans.*, vol. v., page 10.

it were subject to spontaneous combustion. Very few seams could be worked by longwall if they were subject to spontaneous combustion, and he should hesitate to open a mine on such lines. If they opened a certain district and a fire took place, and was not sealed off, they ran a risk of losing the whole colliery. It compelled them to make the workings into panel-work. They could only work a district, say 300 feet square, when there were signs of heating, but the fire gave very little warning of its approaching outbreak, and there were many matters to be taken into account. For instance, if the mine gave off fire-damp, it was essential to prepare for sealing off as quickly as possible. But there were other mines where the gases differed, and where they could get the stoppings in, the fire would generally die out. He avoided working such a seam on the longwall system, and adopted the smaller system of panel-working. If they could send the hussle out of a mine, gob-fires in that mine would be reduced to a minimum. Fires seemed to take place more frequently if the rider coal was left in. That would have something to do with it, because it could not resist the exciting heat or pressure which it might get from time to time. They must come to this conclusion—that at all times they must exclude the air from the goaf, and wherever hussle was, on or beneath the coal, they ought to take every precaution. It was a dangerous substance, and caused most of the gob-fires in the district.

Mr. J. R. Haines said he did not think they had any evidence that hussle was put into the packs. He agreed with Mr. Mitcheson, that the top coal constituted a far more important point than the hussle, particularly when they had a roof similar to that over the yard coal-seam. He (Mr. Haines) thought that coal so liable to spontaneous combustion as the yard coal should only be wrought in panels. If not, the headings should be conducted to the far end and worked homeward. It was not possible to do this in some instances; nor would it prevent gob-fires, but it would enable them to be dealt with more effectively, and at less loss.

The President remarked that it was not everybody who was so favourably situated that they could afford to wait and drive to the boundary before drawing coal. As a rule, so soon as the seam was reached there was a demand for coal. A system of panel-work ought to be carried out where there was a liability to gob-fires. If panels were worked with only small pillars the pillars were lost, but if the pillars could be left large enough to be worked subsequently there was economy in so working the coal-field. Mr. Settle emphasized the part which hussle played in gob-fires. He thought that there was no colliery in that district subject to gob-fires in which hussle was absent. There was another point—that

wherever there was a sandstone-roof which broke into large masses they rarely saw any heating in the goaves. He did not know a single instance of a gob-fire under a sandstone-roof.

Mr. MITCHESON said that one reason he referred to the top coal was, that the great row seam also gave considerable trouble, and the conditions of working were the same in the latter seam as in the yard coal-seam. In the great row seam they worked under the top coal, but there was no hussle. In the ash coal-seam also there was top coal, and in this seam gob-fires were frequent. With regard to the sandstone-roof, the Oolitic coal in Sutherlandshire, which lay under such a roof, was more liable to spontaneous combustion than any coal-seam he had ever seen.

The PRESIDENT asked what was the nature of the coal?

Mr. MITCHESON said that it was black lignite, but there was a sort of bastard cannel in the seam.

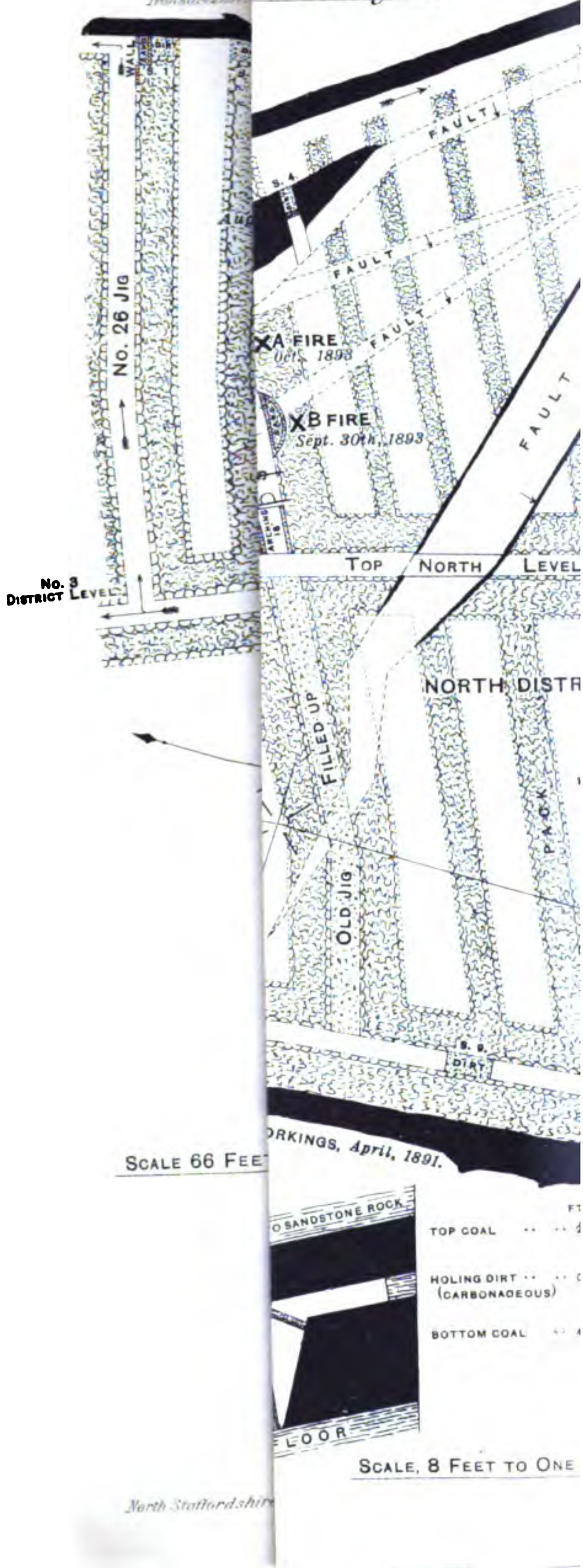
Mr. W. N. ATKINSON said that he was under the impression that there had been gob-fires in North Staffordshire under rock-roofs.

Mr. SETTLE said that the Banbury seam had a rock-roof, and was liable to gob-fires.

Mr. HASSAM said he was of opinion that with a seam of coal not more than 4 or 5 feet thick, it was better to work it by longwall than by the panel-system. Every fire in the yard seam had occurred in the packs. The packs were built chiefly of hussle, with walls of stone.

Mr. MITCHESON moved a vote of thanks to Mr. Hassam for his paper.

Mr. SETTLE seconded the motion, which was agreed to.



No. 26 Jig
Fault
A Fire
B Fire
Sept. 30th, 1893
Top North Level
No. 3 District Level
North Distr
Filled Up
Old Jig
Pack
Dirt
rkings, April, 1891.
Scale 66 Fee
Sandstone Rock
Top Coal
Holing Dirt
(Carbonaceous)
Bottom Coal
Scale, 8 Feet to One
North Staffordshire

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
DECEMBER 10TH, 1894.

MR. E. B. WAIN, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. W. E. BENTON, Midland Coal and Coke Co., Limited, Apedale, Newcastle-under-Lyme.
Mr. JOHN WALTER BYRNE, Lawton Road, Alsager.
Mr. CHARLES T. HULETT, Lilleshall Collieries, St. George's, Wellington.
Mr. JOHN WILLIAM PACEY, Burley Cottage, Apedale, Chesterton.
Mr. JOHN YOUNG, Cliffe Villa, Shelton, Stoke-upon-Trent.

ASSOCIATE MEMBERS—

Mr. PERCY MOTTERAM COX, Stoke-upon-Trent.
Mr. JOHN E. PERRY, Wolverhampton.

ASSOCIATES—

Mr. WILLIAM HADLEY, Shelton Steel and Iron Co., Limited, Stoke-upon-Trent.
Mr. GEORGE ERRINGTON WHITFIELD, Fegg Hayes, near Tunstall.

STUDENT—

Mr. RICHARD B. LYNAM, Shelton Steel and Iron Co., Stoke-upon-Trent.

Mr. JOHN NEWTON read the following paper on "Railway-waggon Axle-boxes, and the Mode of Manufacturing them from Steel Plate":—

RAILWAY-WAGGON AXLE-BOXES, AND THE MODE OF MANUFACTURING THEM FROM STEEL PLATE.

BY J. NEWTON.

In bringing the subject of axle-boxes before the members, it will be necessary to go back several years and make a comparison between the old form of cast-iron axle-box, the improved form of cast-iron axle-box, and the stamped-steel axle-box—the subject of the present paper—and ascertain whether the general requirements of railway-waggons have been satisfied by each successive improvement.

Figs. 1, 2, and 3 (Plate XIX.) show the grease axle-box in general use about forty years ago. It is, in many cases, used on private owners' waggons at the present time, with one difference, that the upper part of the grease-chamber is now closed over by the casting instead of by a loose piece of iron, carrying the lid attached (Fig. 3). The axle-guard, guides, and spring seat are exceptionally weak. As this axle-box has no bottom, the axle-journal is exposed to the effects of dust and dirt.

Fig. 4 (Plate XIX.) shows another form of axle-box made in two parts, with bolts holding them together and securing the spring to the axle-box. This form is gradually going out of use, although it was less susceptible of fracture than that taking the buckled spring: the bolted spring, being firmly attached to the box, reduced the shock or blow when the waggons were bumped roughly one against the other. However, the cost of maintenance in keeping the nuts tight, owing to the elasticity of the spring, and the difficulty in removing the nuts when one was desirous of examining the interior of the boxes neutralized the other advantages of this axle-box.

Fig. 5 (Plate XIX.) shows a form of oil axle-box used for waggons about the same period; it is still used on some of the railways, but its general application is more especially confined to railway-carriages.

For many years little or no alteration was made in the general design of axle-boxes, until the increasing volume of railway traffic necessitated heavier loads, higher speeds, allowed shorter time for collecting and distributing waggons, required increased siding accommodation, and other improvements, any one or all of which contributed to shorten the life of the waggon, and more particularly the life of the axle-box. Greater atten-

tion was necessarily accorded to railway-waggon sto
that draw-gear, buffer-gear, springs, wheels, and a
much improved, and the breakages, etc., considerabl
went on, the competition for traffic became keener,
dealing with it were much improved, hydraulic ma
into use for working tip-tables, hoists, capstans, and

Demand was next made for waggons to carry h
strengthening them for this purpose, amongst other p
stronger axle-boxes became necessary. The margin
in cast-iron being so small, other material to be use
of axle-boxes became a necessity. Attempts were n
but the form of an axle-box does not lend itself read
in this material, the result being that bad and un
frequent, and a consequent increased cost of produc

Another system of manufacture was tried in Ge
in which the sides, bottoms, and ends of the axle-b
half-puddled iron, which was placed in a mould at
shaped by a die. These boxes, for convenience in ma
in two parts which were bolted together. As the pa
after being stamped they were somewhat costly, but
was much greater than that of cast-iron, it was fo
them.

The next substitute, mild plate-steel, has, up
proved the most efficient and reliable successor of c
some explanation of this subject may be instructi
members.

Before describing the process of its manufact
may be interesting to define the causes of break
which a box must possess to resist all the shocks
axle-boxes are subject. They are as follow :—

(*a*) Axle-boxes are broken or fractured by se
bumping of waggons one against the other, causin
or roll from the bearing and strike against the s
bumping is becoming more severe day by day, ov
of steam-brakes and their irregular use on goods e

(*b*) The sudden stoppage of a waggon while s
worked by a rope from a hydraulic capstan, throv
against its cast-iron guides, and fracturing or
sudden stoppage of a waggon may also occur on a
engine slackening speed for signals and starting agai

of the train has quite ceased, causing a bump or series of bumps, and if a lug fails or a spring is jerked out in consequence, the train may be partially de-railed.

An axle-box offering resistance to the strains above-mentioned, and combining all the elements of strength without increased weight, elasticity to blows, with facility for rapid examination and changing of the bearings, is the axle-box required at the present time. It represents economy by its indestructibility, and in saving detention of waggons. If private owners, therefore, would look carefully into this matter, that distinctly weak part of a private waggon, the axle-box, would soon be remedied.

Attention may be directed to the increased facilities now introduced for the examination of journals and cleaning of grease-chambers, most important items in the life of an axle-box. The credit for this improvement is due to Mr. Attock, of the Lancashire and Yorkshire Railway Company, who for some years has carefully studied the question. The working of his axle-box is so satisfactory that the manufacturers of the stamped-steel axle-box consider it the best one to adopt as a standard for private owners' waggons.

The following are some of the important features of the stamped-steel axle-box shown in Figs, 6, 7, 8, and 9 (Plate XIX.) for grease:—The outside shell is formed of a mild steel plate stamped by machinery into shape, and of uniform thickness and strength. It is fitted with two inside plates having projections to prevent the axle from rolling off the bearings, and a recess to retain the bearing in position is rivetted to the outer shell. The thrust is taken off the rivets by the plate fitting into the crown of the box and into the bottom, and as the bottom fits into the side guides, the whole strain is thrown on the strong corrugated outside shell. A loose grease-chamber, which can be easily withdrawn for cleaning, slides underneath the spring-seat, the projections sufficing to retain it in position. The arrangement is also supplemented by the steel sliding-front, which is now so generally used. The grease-chamber is fitted with a steel lid which protects the spring from the effects of the weather, or from damage in any other way. All parts of the box, which are made of steel, are made in dies, in an absolutely finished condition with guaranteed uniformity, besides having the advantage of the hard skin of the metal on all the surfaces.

Figs. 10, 11, and 12 (Plate XIX.) show the stamped-steel oil axle-box.

The process of stamping hot steel plates has always been a very difficult one, when preserving the thickness of the metal was essential.

Although a very simple matter now, it has taken a long time to solve the many problems that arose, and many ingenious appliances had to be devised to produce the various forms of axle-boxes required. All the presses used for stamping are power presses, and weigh about 12 tons each. They are powerfully geared, and work at a speed of 26 strokes per minute.

Figs. 13 and 14 (Plate XIX.) show a rectangular plate (which is heated) resting on a matrix or mould with the upper die descending. The dies form a kind of toggle-joint, and Fig. 14 shows the position assumed by the toggles at the bottom of the stroke, the toggle being arranged so as to follow the flow of the metal. This operation is simply one of bending, and it depends upon well-known practice in stamping solid metals into shape under a drop or steam-hammer, that once you get the quantity of metal required the operation of displacing it is an easy one.

The plate which comes away from the last operation is red-hot, but not quite hot enough for the next two operations, so it is placed in a furnace and re-heated. The same idea is carried out in the operations shown in Figs. 15 and 16 as in Figs. 13 and 14.

The plate is then put into a press fitted with cutting tools, which cut the plate or blank ready for flanging and folding (Figs. 17 and 18).

These operations require a press that opens to receive and remove the plate, and the plate must be held exactly in position before the rollers commence to work, and retained there until they have finished and returned to their normal position, when the table lowers itself, and the plate is taken out and placed in the folding-machine.

Figs. 19 and 20 (Plate XIX.) show the mandril, representing the inside of the axle-box, on which the plate has to be folded. The figures also show the plate in position held up to the top die at a pressure of about 10 tons, and the rollers ready to commence operations. The dotted lines represent the roller after passing down the side of the box and about to return to its normal position; the table is lowered as in the flanging press; and the mandril, which is hinged at the bottom end, is turned over and the axle-box taken off.

After being folded, the corners at the back of the axle-box are naturally bulged or puckered. The box is then placed upon a die, and is heated by means of a powerful gas blow-pipe and the projections welded and hammered down, the back being taken out to the diameter required by a cutting-machine, while with the same heat it is being blocked true.

The axle-box is completed by making the inside pieces and bottom

secure to the shell, the holes being drilled through templates so that the parts are interchangeable, and then rivetted up cold with rivets.

The stamped-steel axle-box is not only practically indestructible, and if a call should be made for heavier waggons, has a margin of strength which no cast-iron axle-boxes can possess without proving a most unwieldy addition to the waggon, and every $\frac{1}{16}$ inch of metal added to the thickness of the plate of the stamped-steel axle-box increases its strength fourfold.

The owners of private railway-waggons ought seriously to consider these points, namely, that to make a perfect axle-box everything in connexion with it should be of the best material, the bearings should be of "specified quality," and the grease equally good. These factors being assured, it may be taken for granted that all has been done to prevent the detention *en route* of waggons, which is one of the most important items in the expenditure on waggon repairs.

The PRESIDENT said the axle-box described appeared to be indestructible. He thought that in building new waggons some such box should be used, but he should like to have some information as to the actual life of an ordinary axle-box. Then as to axle-guards, he thought there was more damage done to axle-guards than to the boxes.

Mr. COWLISHAW thought that the metal being so thin down the guides they would soon be worn through.

Mr. NEWTON answered in the negative.

Mr. COWLISHAW said that there was a certain amount of friction from the up-and-down motion which must produce wear.

Mr. NEWTON said that was so. Referring to the remarks of the President, he (Mr. Newton) could not quote the average life of an ordinary box. But in sending a waggon from Wheelock to Grimsby, for instance, a cast-iron box might get broken and the waggon might be stopped. It would be broken, if there was rough usage, perhaps before half the journey was accomplished, entailing a loss which would mean the extra cost of an unbreakable box. If a cast-iron box could be always run without accident it would last as long as others, but the chances were that it would get broken before it was worn out. He could not say much about axle-guards, but he did not think that as a rule they were liable to get broken. Mr. Newton then explained, by reference to drawings, how they prevented the steel plate from becoming thicker in one part than another.

The PRESIDENT proposed a vote of thanks to Mr. Newton for his paper.

Mr. MITCHESON seconded the motion.

Mr. HAINES, in supporting the proposition, asked Mr. Newton the relative cost of an ordinary cast-iron box and the steel box to which he had called attention. It was inconvenient to have a breakage of an axle-box, causing a stoppage of the waggon. If an axle-guard got broken they were generally told it was an old flaw, but if they could strengthen the axle-box and the guard as well, they would do a great deal towards increasing the continuous running of railway-waggons.

The motion was carried unanimously.

Mr. NEWTON, in replying, said that the cost of the box which he had described was 15s. 6d. net.

Mr. HAINES said that he paid 10s. 6d. for cast-iron axle-boxes.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE MASON COLLEGE, BIRMINGHAM, DECEMBER 6TH, 1894.

MR. A. SOPWITH IN THE CHAIR.

The minutes of the last General and Council Meetings were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. GEO. W. WARING, Mining Engineer, Dudley.
Mr. GEO. F. READER, Chasetown, Walsall.

STUDENTS—

Mr. ROWLAND C. WEBB, Mining Student, Camborne.
Mr. JOHN B. MOXON, Cannock Chase Colliery, Walsall.

Mr. E. J. BAILEY read the following paper on "Electric Haulage by the Main-and-Tail Rope System":—

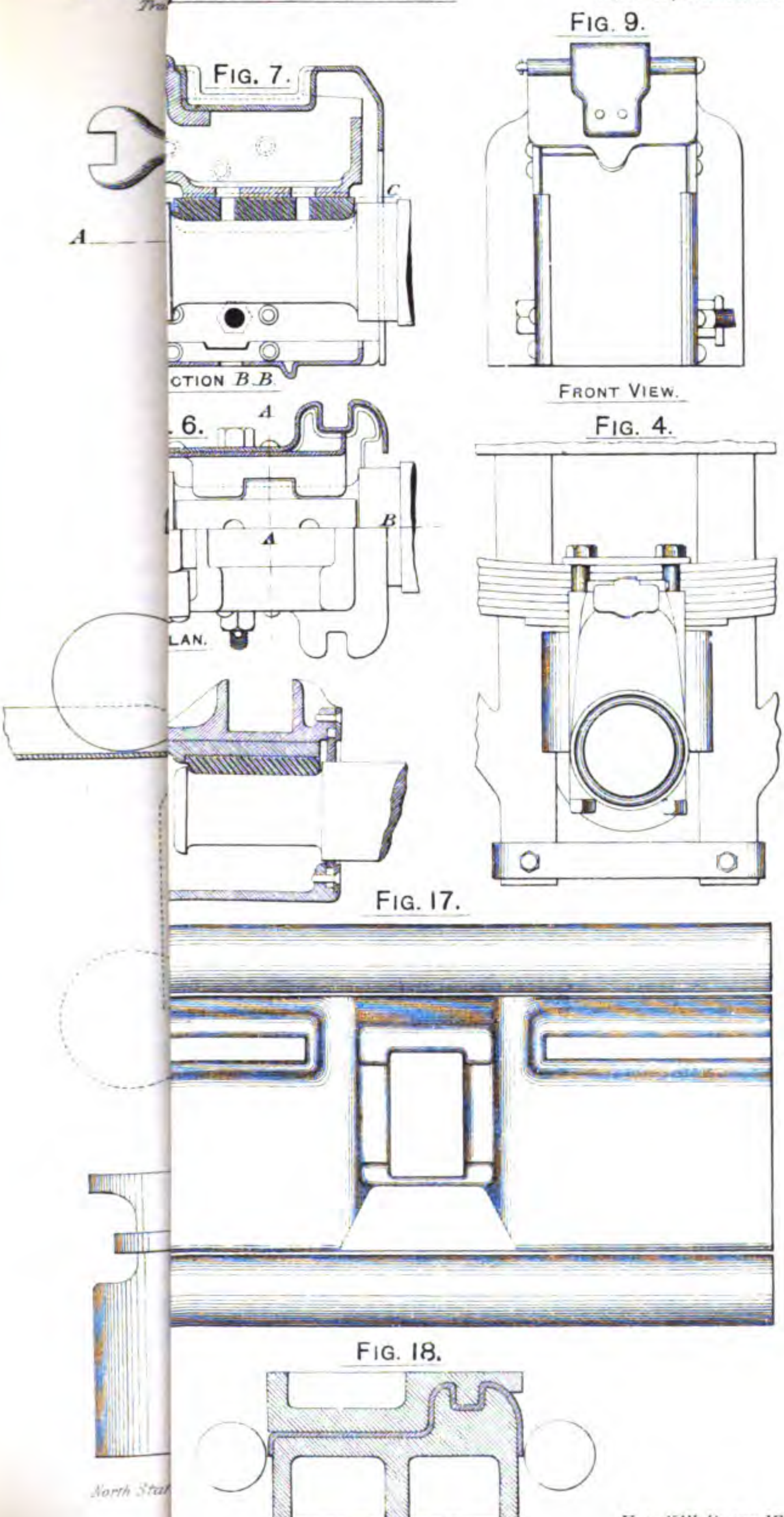


FIG. 9.
FIG. 7.
C
A
CTION B.B.
FRONT VIEW.
FIG. 4.
. 6.
A
B
A
LAN.
FIG. 17.
FIG. 18.

ELECTRIC HAULAGE BY THE MAIN-A SYSTEM.

By E. J. BAILEY.

Many valuable papers upon electricity as a m have been read before the various institutes foı Institution of Mining Engineers, and the records a members.

In going over a somewhat beaten track the au notes with the view of describing an electric-pov underground haulage on the main-and-tail rope placing before the members a few ideas gathered during the last five years.

This plant is working at the Abercanaid collie Plymouth Company, Limited, of Merthyr Tydvil principal coal-seam worked is the 5 feet 6 inches (about 3½ feet thick, and consequently a large area maintain the output of about 5,000 tons per we re-opened (after being closed by fire about twenty-fi So rapidly have the workings extended that the qı haulage-system had to be seriously considered, 4(being exhausted annually.

In 1890, it was found that to maintain th(impossible to meet the haulage requirements from extending the endless-rope driven direct by an engi then working to B (Fig. 2, Plate XX.). A double- trams used in South Wales must be 12 feet in very heavy expenditure each time that the en(farther in-bye; besides, the time taken in making serious impediment to the rapid extension of haul single-road, therefore, worked by main-and-tail the only way of following up the rapidly extendiı mechanical haulage.

The power necessary to work this haulage wa decide. Compressed air was considered, but elect more economical, and indeed the most practical

power to a point underground ½ mile from the pit-bottom. The plant described below was thereupon put down in 1890, to bring the coal from the double-partings near the working-faces, to the end of the endless-rope system.

The surface generating-plant consists of a Marshall compound condensing engine with cylinders 13 and 21 inches in diameter respectively and 2 feet stroke, working at 110 revolutions per minute, and driving (direct off a 12 feet diameter and 18 inches wide fly-wheel by a belt 15 inches wide) a generating dynamo of Crompton type and horizontal pattern, built on a wrought-iron girder bed-plate. The dynamo is compound-wound, and capable of giving 200 ampères at 500 volts when running at 550 revolutions per minute.

The conducting cable, 9,600 feet long, is carried down the downcast shaft and along the main endless-rope haulage-road to the underground motor at B (Fig. 2, Plate XX.). This cable has been specially constructed to resist falls. It can stand a shearing strain of 10 tons per square inch, and is made up of 37 wires of No. 14 B.W.G. high conductivity copper wire, highly insulated with vulcanized bitumen, double-taped, and served with two layers of jute yarn compounded between each; and it is protected by a double sheath of No. 8 B.W.G. steel wires (the first stranding being of 30 wires and the second of 36 wires, laid up in a direction reverse to the first). The cable is of ample size to carry the current of 200 ampères, and the loss of potential does not exceed 50 volts or 10 per cent.

The underground motor is a series-wound machine of Crompton type, built to run at 600 revolutions per minute, and to work with 185 ampères current at 450 volts; at starting, when a higher current is required, it will take 300 ampères without harm. The motor is placed horizontally at one end of a wrought-iron frame, which forms a bed for the drum and spur-wheel. The drum-shaft, which is of steel, is driven by a countershaft by means of spur-gearing (geared 6 to 1), and the motor drives the countershaft by means of six 1 inch hemp ropes (3 to 1). The two drums, 3½ feet in diameter and 1 foot wide, are fitted with clutches and foot-brakes. The motor, drums, etc., shown in detail in Fig. 1 (Plate XX.), are fixed at the end of the endless-rope haulage at B on Fig. 2 (Plate XX.) over the main-road.

Five separate districts, worked by the motor, are shown in Fig. 2 (Plate XX.), and are as follows:—

No. 1 *District, New Graig.*—This is a new district, and is shown from C to D (Fig. 2). It is a dip road started to recover the 5 feet 6

inches coal-seam from royalties lately added to the colliery taking. At present, the length is only about 150 feet; but it will have a length of 1,200 feet before reaching the boundary at a gradient of 3 inches per yard.

No. 2 District, Brecon's Dip.—This dip is shown from E to F (Fig. 2), a distance of 1,800 feet, and is of a gradient varying from 1 to 8 inches per yard (caused by the downthrow faults crossed by the workings). All the coal worked to the rise, up to the main-level, is collected at the double-parting F, and drawn back by the electric haulage-motor in journeys of 15 trams to B.

No. 3 District, Main West Level.—This level is shown from B to H (Fig. 2), a distance of 1,650 feet, and is dipping from 1 to 3 inches per yard. At the double-parting H, all the coal from the working-faces to the rise is collected and drawn by the electric haulage-plant in journeys of 32 trams back to B.

The above districts are all situated in the 5 feet 6 inches coal-seam; two others are also worked, viz.:—

No. 4 District, 9 feet and 6 feet Coal-seams.—From G to I (Fig. 2) is a double-parting at the bottom of a rise cross-measures road, driven to the 9 feet and 6 feet coal-seams from the 5 feet 6 inches coal-seam at G. From this parting, the produce of the 9 feet and 6 feet coal-seams are collected and drawn in journeys of 20 trams back to B.

No. 5 District, Gellideg Coal-seam.—From C to J is a cross-measures dip, dipping about 10 inches per yard, and driven to the Gellideg coal-seam lying about 45 feet below the 5 feet 6 inches coal-seam. A level from J to L and a dip from K to M with double-partings at L and M are working, and the haulage draws journeys of 10 trams from them to B.

The average weight of the full trams is 30 cwts. each, consisting of 22 cwts. of coal and the weight of the tram, 8 cwts.

The full loads brought back from each district are as follows:—

No. 1. At present only opening out.
No. 2. Trams per journey 15, weight 22 tons.
No. 3. „ „ „ 32, „ 48 „
No. 4. „ „ „ 20, „ 30 „
No. 5. „ „ „ 10, „ 15 „

The main, and also the tail-ropes, working the empty journeys in, are shown, as well as the pulleys, etc., in Fig. 2 as continuous lines.

Besides the above loads, the weight and friction of ropes should be added, and in No. 2 district the friction of the ropes at the curve E is considerable.

The trams run at a speed of about 4 miles per hour on the dip-roads, and from 5 to 6 miles per hour on the level-road.

The haulage from five districts deals with about 1,000 tons of coal in ten hours from the double-partings to the point B, and a considerable quantity of rubbish has to be raised.

In addition to working the haulage, the electric plant works two pumps underground and one on the surface (for condensing purposes).

The following are the most important points in connexion with the general working of this installation :—

The variable load put on to the motor has been the chief cause of trouble. When starting a full journey of trams, and putting the underground motor to its full power, it has a tendency to check the speed of the steam engine, whereby the voltage is dropped and the work done by a heavy increase in the electric current. This might be avoided by the engine-power being considerably over its normal work, and equal to the extra demand made upon it when starting the loads, and being thus able to follow up the speed of the dynamo.

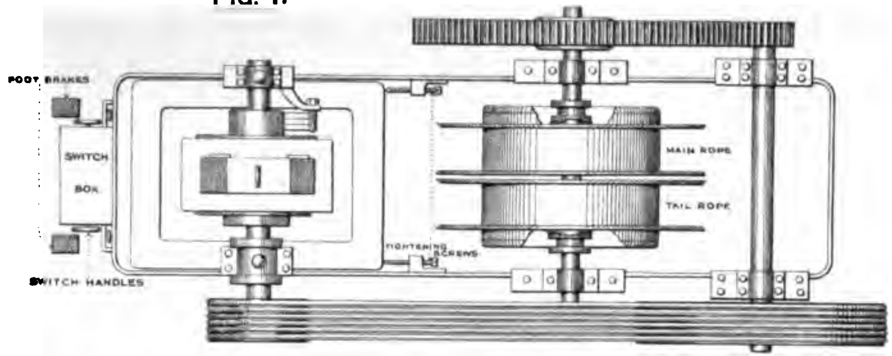
It is most desirable that the load and work of the engine should be equalized. This could be done by employing accumulators of suitable size which would enable the combined efficiency of the engine and dynamo to be maintained during the whole period of their working; whereas now it varies from nothing to a high maximum. The cost of accumulators would be, however, a very serious item.

The resistance required in putting on the current, so as to get a gradual application of the power, is a point certainly open to improvement. At present the resistance is composed of galvanized iron wire, coiled on a frame placed in the full current of intake air so as to keep it cool.

The brushes used on the dynamo are a combination of carbon and copper, and to prevent the injurious effect of sparking and the consequent burning of the brushes caused by the variable loading, they are slightly shifted on the commutator from time to time by a boy kept for the purpose, the difficulty being thus to a great extent overcome. The brushes on the motor are carbon, and no trouble has been experienced with them. Duplicate armatures for both dynamos and motor are kept, so that they can be changed periodically for cleaning and examination.

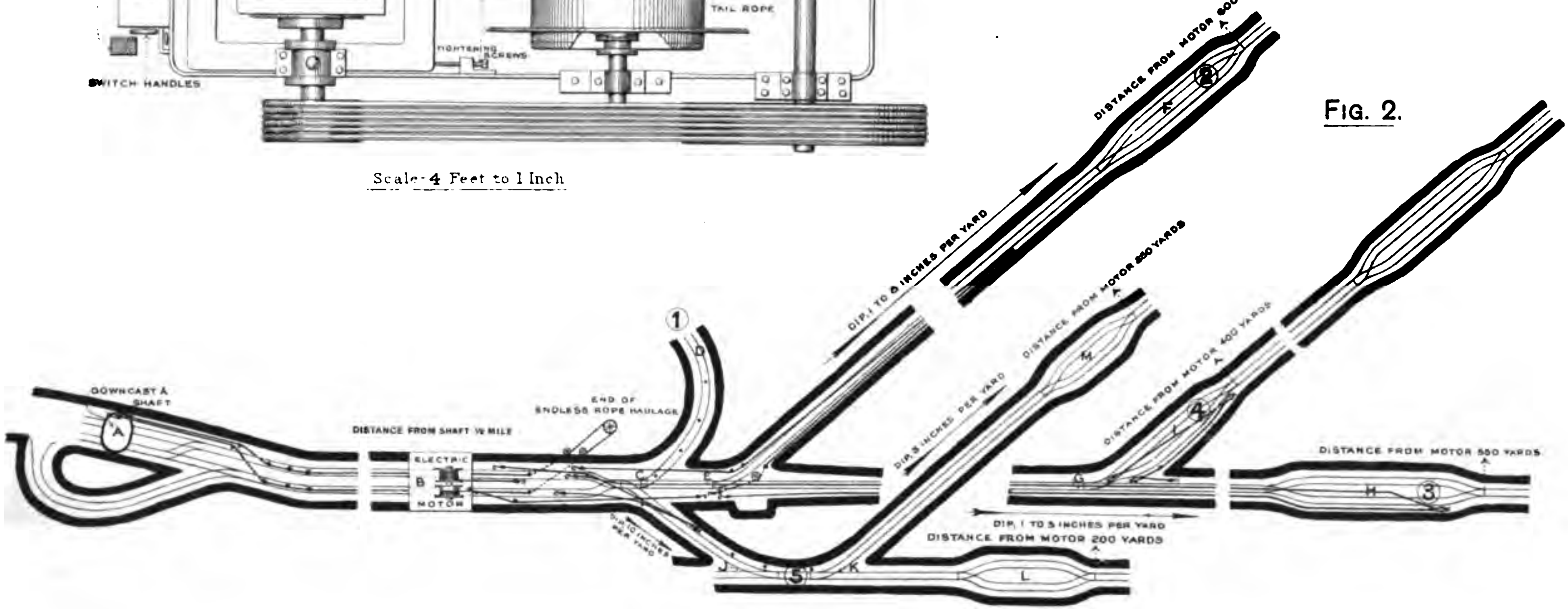
The conducting cable has given satisfaction so far, but it is possible that the heavy armour covering has a tendency to pull the cable out of the centre of the insulation when the rope is passed round sharp bends and curves. It is also the cause of some trouble when testing is necessary, as it is awkward to get at, being laid below the rails.

FIG. I.



Scale - 4 Feet to 1 Inch

FIG. 2.



Andw Reid & Compy Ltd Newcastle o/Tyne

The delicate construction of electric fittings keeping them in good order underground somewhat by very careful supervision that this can be satisfact

The important question of safety underground h case in working the haulage and pumping motors, each instance in the intake air-ways and on the out- stations.

Taking into consideration the amount of work wl doing, as well as the trying character of the condi has to do it, the results obtained are very satisfactor for its introduction.

This electric-power plant was the first of the kin Wales, and possibly one of the first in this country difficulties were met with in its inception. Most of been overcome, and no doubt those still remaining near future.

Numerous electric-power plants are now at w work, under similar conditions in all parts of this co between electrical and mining engineers will, no doul already gained, bring the use of electric power in r efficiency.

The writer is sorry that he is not able to add to of tests made to show the useful effect of the plant.

The Electric Power Committee of the Soutl Engineers, in conjunction with the writer's brothe are about to make some very complete tests upon tl will be pleased to submit their results at a fu Institute as a supplement to the present paper.

A somewhat unreliable test, made recently, gav of about 65 per cent., which can only be accept result.

The Chairman thanked Mr. Bailey for the pa papers like that he had read were always very records for reference. It was a paper which woul discussion, as mining engineers were especially in of electric transmission of power.

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country upon which they had originally been deposited. The floor of the old Carboniferous land was warping and folding during the whole of the Carboniferous period, and where the folds brought up Carboniferous areas above the sea-level, there the earlier Carboniferous rocks became washed off. Where other areas became more greatly depressed in these folds, the material removed was laid down locally in the form of sandstones, conglomerates, and shales; so that in one district all the various coal-seams may now occur together with great thicknesses of coarse measures between them, while in another, the lower coals may be wholly missing, and the upper coals may be found to completely overlap the edges of the pre-Carboniferous floor. This overlapping seems unquestionably to be the fact in certain parts of the Forest of Wyre. In the Coal-measures of South Staffordshire one found, now and again, abundant conglomerates and thick sandstones and shales containing pebbles and fragments of the old rocks up to the Carboniferous Limestone, affording clear evidences of the earth-movements, local erosions and depositions going on in the Midland and Western districts during Carboniferous times. The peculiar Epsley group, the Halesowen Sandstone group, etc., are all of remarkable interest when studied from this point of view. Phenomena like the dreaded Silurian Bank and such like, possibly owe many of their characteristics to Carboniferous earth-movements. The study of these old crust-movements will be found to become of more and more economic importance as time goes on, and their study has a most vital bearing on the search for coal both east and west of the South Staffordshire coal-field. One of the first requisites in studying these Carboniferous earth-movements and their consequences is to map out the warpings of the various coal-seams as they now exist, and so work back from the present to past times. The speaker hoped, in the course of a short time, to bring before the Institute a plexographic map of some of the South Staffordshire coal-seams, which was in preparation by himself, Mr. Martin, and Mr. King, and such maps would be certain to be drawn eventually by geologists for every coal-field. In the preparation of such maps and their interpretation, it was necessary to have sections of as many shafts as possible, and he trusted that the members and others, who had unpublished sections, would kindly lend them for this purpose. He was glad to see how frankly Mr. Jones had placed his sections at the service of the working geologist, and they would be of the highest value in studying the warpings and erosions of the Coalbrookdale coal-field. Mr. Jones had done such good work among the Carboniferous strata of the Western Midlands, and had shown so clearly the economic bearings of his

scientific researches, that he (Prof. Lapworth) hoped that in the course of time he would see his way to publish the remainder of his accumulated information for the benefit of the mining world.

Mr. T. CROSBEE CANTRILL (Bewdley) said he had stated at the opening of the discussion that he had found a supposed *Spirorbis* limestone in Permian ground in the district under notice. He had since sent up a specimen to the British Museum (Natural History) for examination, and he hoped to hear the result very shortly. If this specimen should prove to be *Spirorbis* limestone, they would have to regard as Coal-measures what had hitherto been considered as Permian measures.

The discussion was continued, in brief terms, by Mr. E. B. MARTEN, Mr. W. B. COLLIS, and Mr. GEO. A. MITCHESON.

Mr. JONES, in reply, said that Mr. H. W. Hughes objected to the words "Where the Coal-measures occur in a regular sequence and undisturbed, as at Sandwell Park colliery." He (Mr. Jones) admitted that the passage required qualifying, and suggested for approval the following :— "Probably we have at Hampstead and Sandwell Park collieries as near an approach to a regular sequence as we can find in this district, and at Sandwell Park colliery we find there is a distance of 885 feet between the *Spirorbis* limestone and the thick coal." Mr. T. Crosbee Cantrill spoke of the occurrence of *Spirorbis* limestone in what have been considered by the Geological Survey as Permian rocks. The line of demarcation between the Permian and Upper Coal-measures has not yet been drawn, and there is no more debatable ground. If the band of *Spirorbis* limestone found in what we suppose to be Permian is shown to be a continuous band as it was originally deposited, there would be every reason for supporting Mr. Cantrill's suggestion. He did not know how much further he had carried his investigation, but so far as he knew there was no band of *Spirorbis* limestone where the main sulphur coal-seam did not occur, and when it was found embedded with other rocks in the Permian it was in the nature of a shingle-beach, as both the black and cream-coloured kinds are found, and seem to be referable to the two bands of similar colour found in the Coal-measures; moreover, the beds Mr. Cantrill referred to held the same horizon as the conglomerate at Alberbury and Cardeston mentioned by Sir R. Murchison, and described by him as Permian conglomerate. Prof. Lapworth, at the first reading of the paper, "did not quite concur with all the arguments adduced as to the correlation of the South Staffordshire and Coalbrookdale coal-fields." It was, of course, a very important point in the line of argument employed in his (Mr.

Jones') paper that such a correlation should be established, and as the subject was treated in a somewhat sketchy way in the paper, giving only a few indications of the comparisons; and taking it for granted that the reader had read all the literature upon the subject, he thought it desirable to send Dr. Lapworth his paper on the "Correlation of the South Staffordshire and Coalbrookdale coal-fields."* In support of the attempted correlation, he (Mr. Jones) would mention that the paper was placed in the hands of Sir A. (then Prof.) Ramsay soon after it was written, because he had observed that in his evidence he had stated that any attempt to correlate these coal-fields would be fruitless. He wrote him (Mr. Jones) a letter dated September 30th, 1869, in which he says:—"At length I return your memoir (on the Correlation of the South Staffordshire and Coalbrookdale Coal-fields) which I have gone over twice with great pleasure and much instruction. It is a most valuable contribution both to the scientific and economic geology of the districts, and by-and-by, when the report comes to be written, I should like to make free use of it, or, indeed, if not too late, and if you approve of it, I do not see why it should not be printed entire in the evidence." In the end an abstract was printed in the Blue Books of the Royal Coal Commission. The late Mr. Henry Johnson, of Dudley, who was very well known as a practical mining engineer, wrote to him (Mr. Jones) on October 20th, 1872. "I have read your paper with very great interest and pleasure. Substantially I agree with all you have said, and I think you have put it in a very clear and logical manner." A correspondent, criticizing this paper, thought that the thicker coal-seams up to 5½ feet at Rock might be the equivalent of the Kinlet and Harcott coal-seams. He said that some of them were not sulphureous, and he thought that the *Spirorbis* limestone was a fair mark, but not to be trusted as a geological horizon. Why should not there be lower coals at a greater depth? Of course, at Abberley, opposite the Hundred House, the Silurian limestone is nearly perpendicular, and that might point to a deep Carboniferous basin. He (Mr. Jones) considered that the *Spirorbis* limestone was the safest geological horizon, ranging as it does from Lancashire and Cheshire into Denbighshire and Shropshire, Worcestershire, Staffordshire, and Warwickshire. As the coal-seams at Rock rest upon Old Red Sandstone, the Coal-measures can have no great depth unless there be a trough caused by faults, and we have no indication of them. If there were deeper coals, why did they not show themselves at the outcrops as did the *Spirorbis* limestone and the sulphur coal-seam? There was no

* *Trans. South Midland Inst.*, vol. ii., 1870.

indication of such a trough. The association of the *Spirorbis* limestone fixes these coal-seams as upper coal-seams. The Geological Survey estimates them at 600 feet in its greatest thickness. The dislocation of the Silurian rocks at Abberley date back to pre-Carboniferous times, and were perpendicular when the Coal-measures were being laid down. Mr. Henry Johnson thought it was probable that "the yard coal" and "yellow ironstone" of the Shropshire coal-field were the representatives of the "heathen coal" and "gubbin ironstone" of South Staffordshire. That depended upon the value of the "table bat" as a datum-line. His (Mr. Jones') opinion was that it was a reliable datum-line, because few strata of this character were to be met with in the whole series. He considered it to be the equivalent of the pitcher basses of Shropshire. Although, in the neighbourhood of Dudley, the little gubbin ironstone lies directly on the heathen coal, without any intervening table bat (which is badly represented about Dudley), it thickens in every direction from that point from a few inches to 4 feet. It is a stratum with distinctive features, and compares well with the pitcher basses of Shropshire. The yard coal and yellow ironstone of Shropshire lie some feet above the pitcher basses, the heathen coal in Staffordshire occurs below the table bat, therefore if the table bat and the pitcher basses are the same measure, the heathen coal, which is below, cannot be the same as the yard coal-seam, which lies above the table bat horizon. The correlation depends upon the value and reliability of the table bat as a datum-line. We can only say that there is scarcely anything like it in the rest of the strata either in South Staffordshire or Shropshire. We must, therefore, look into the question of its persistency—the tendency is for it to increase in thickness to the northward. Prof. Prestwich describes the pitcher basses as "A very bituminous slate-clay." Prof. Jukes describes the table bat as a very compact bituminous shale, splitting into large slabs, which, when first exposed, look firm, but soon crumble to pieces." Probably the identity of the two may be settled by a further examination of the fossil remains found in each. He (Mr. Jones) had listened with much interest to Prof. Lapworth's remarks, and he was pleased to find that Prof. Lapworth confirmed many of his views. It was a large and important subject, and he commended it to the attention of the members.

On the motion of the Chairman, a vote of thanks was passed to Mr. D. Jones, Mr. Henry Johnson, and Mr. Bailey for their papers, and the proceedings then terminated.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS,

AND

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

JOINT EXCURSION
To Shireoaks Collieries and Welbeck Abbey, September 27th, 1894.

Mr. C. TYLDEN WRIGHT, in the Chair.

The following gentlemen were elected:—

MEMBER—

Mr. Edward Ellis Booker, Colliery Manager, St. John's Colliery, Staveley, Chesterfield.

STUDENT—

Mr. George Catterall Leach, Surveyor and Draughtsman, Birchill Lodge, Hasland, Chesterfield.

The party arrived by different routes at Shireoaks station, and walked to and inspected the Shireoaks colliery, and afterwards visited Shireoaks church, Steetley colliery, Steetley chapel (a restored Norman fabric), and Whitwell colliery. The visitors had luncheon in the riding school at Welbeck, at the invitation of the Shireoaks Colliery Company, and after passing through the remarkable underground and other state rooms of Welbeck Abbey and the ornamental grounds, drove through the parks to Worksop.

The following notes record some of the features of interest seen by the visitors at the Shireoaks Company's collieries:—

SHIREOAKS COLLIERIES.

The company's coal-field contains about 9,000 acres of the top hard coal-seam (2 feet 8 inches to 4 feet thick), and is situated in the counties of York, Derby, and Notts.

The Shireoaks pits are 12 feet in diameter, and 1,560 feet deep, and were sunk for the Duke of Newcastle in 1859. They are lined with continuous tubbing to a depth of 510 feet, the pressure on the bottom length being 196 lbs. per square inch.

The No. 1 pit winding engine has 2 vertical cylinders 32 inches in diameter and 6 feet stroke. Flat ropes are used, and the shafts are fitted with wooden conductors.

The No. 2 pit winding engine is of similar design, fitted with a conical drum 17 feet to 19 feet in diameter. There are wire conductors, two to each cage, and safety-ropes between the cages. The underground haulage is worked by steam from boilers at the bottom of No. 2 pit, and by air from compressors on the surface. The air-cylinders are 32 inches in diameter by 4 feet stroke, and 36 inches by 5 feet stroke. The endless-rope haulage is on the slow-speed system, with ropes running below the corves. The ventilation is effected by an underground furnace, producing 200,000 cubic feet of air per minute, the water-gauge being 1·5 inches at the pit bottom.

The shops comprise foundry, crucible-steel plant, and waggon-shops.

Steetley Colliery.—The single shaft, 15 feet in diameter, is 1,770 feet deep. The winding engine has 2 cylinders, each 32 inches in diameter by 5 feet stroke. There is a scroll-drum 14 feet to 22 feet in diameter. There are wire conductors, three on the outside of each cage. The underground haulage is driven by compressed air, supplied from a compressor with 2 air-cylinders, 28 inches in diameter by 4 feet stroke. There are 8 Lancashire boilers, 7½ feet in diameter by 30 feet long, fired by Cass mechanical stokers.

Whitwell Colliery.—The single shaft, sunk in 1892, is 15 feet in diameter and 930 feet deep. The winding engine has 2 cylinders, each 36 inches in diameter and 6 feet stroke, fitted with a parallel drum, 24 feet in diameter. There are 3 Lancashire boilers, 8 feet in diameter by 30 feet long, fired with Cass stokers. Ventilation is produced by a Walker fan, 20 feet in diameter by 7 feet wide, driven by rope gearing, 4 to 1.

The workings are inter-connected, and extend 4½ miles from north to south.

The Clown pits are 3 miles from Whitwell colliery, and were not inspected by the visitors.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,

HELD IN THE MUNICIPAL TECHNICAL COLLEGE, DERBY, DECEMBER 1ST, 1894.

MR. WILLIAM SPENCER, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected :—

MEMBER—

Mr. ARTHUR DURY MITTON, Mining Engineer, Shipley Collieries, Derby.

ASSOCIATE MEMBER—

Mr. GEORGE WILLIAM TURNER, Colliery Owner, The Farm, North Wingfield.

ASSOCIATES—

Mr. GEORGE CUTTS, Under Manager, Hartington Colliery, Pentrich.
Mr. THOMAS PATRICK, Deputy, Netherseal Colliery, Burton-on-Trent.

STUDENT—

Mr. PERCY RATCLIFF, Tibshelf Collieries, Alfreton.

REPORT OF THE ROYAL COMMISSION ON "EXPLOSIONS FROM COAL-DUST IN MINES."

Mr. G. ALFRED LEWIS (Derby) said that, although he was only a comparatively young member, he would like to make a few remarks, and as this was his first opportunity of addressing the members of the Institution, he would claim their indulgence. There had recently been published a good deal of literature on coal-dust, explosions also had taken place, and he thought that there had been much light thrown on this subject, and in all probability they were nearer coming to a correct conclusion than they ever had been before. As to literature, he might mention the Report of the Royal Commission on Coal-dust, and a publication upon the recent explosion at Camerton colliery in Somersetshire. Taking the first publication, the four questions the Royal Commissioners put before themselves were these:—(1) Can the circumstances of many explosions, and especially of those on a very large scale and covering a great length of the workings, be fully explained by reference to fire-damp or gas alone?

(2) May the presence of coal-dust, and especially of fine dust, be the sole cause of an explosion? (3) If the coal-dust be in sufficient quantities, will it extend the effect and increase the intensity of an explosion caused by other means? And (4) May fire-damp in small quantities, so small as not to be dangerous *per se*, be dangerous in presence of coal-dust?* He (Mr. Lewis) was of opinion that the second and fourth questions would be those which would cause most controversy. Of course, the difficult thing in connexion with explosions was to say, or to have the possibility of saying, whether there was any gas present at any particular moment or not, but he thought that recent explosions, the circumstances of which were investigated by the Commission, would show that there was the greatest probability that no gas was present, and especially he thought this true in respect of the Camerton explosion. Mr. H. Hall's experiments, although they might not meet with general approval, had a very important bearing on the subject. In one experiment, the cannon was fired into coal-dust and there was no explosion, but after ½ hour's lapse of time the cannon was again fired into the same mixture—without the addition of further dust—and a most violent explosion was produced. That experiment appeared (to him) to emphasize the conclusion of the Royal Commission that coal-dust alone may be the sole cause of an explosion, but there are so many conditions which have to be fulfilled before such an explosion can occur, that it is exceedingly seldom that all these conditions can be fulfilled at the same moment. It did not appear to him, if such were the case, that any colliery could be considered safe from liability to coal-dust explosions, and that was the point he wished to impress upon the members. At the same time, these special conditions or influences might not exist once in the case of 10,000 blown-out shots, but there always was the possibility that such a shot might cause an explosion. He thought that the disaster at Camerton colliery threw some light on the subject—before the explosion, gas had never been found in the workings, nor on the roads, nor even in the mining district, and gas had never been found there since—so that one of the conditions required for a pure coal-dust explosion seemed to be fulfilled. The case had been investigated most thoroughly, and there appeared to be proof that the explosion could not possibly have been produced by any other means but coal-dust through the agency of a shot which was very greatly overcharged, and which would have a very similar effect, and be practically undistinguishable from a blown-out shot. The next question was how to prevent such accidents in the future. He

* *Second Report*, 1894, page viii.

understood that Mr. Stokes would do so by prohibiting shot-firing entirely, but he thought that many mining engineers would consider that to be a very drastic measure. There were other expedients suggested, such as using water-cartridges, lime-cartridges, wedges, etc., to all of which objections are occasionally raised. The great point in his (Mr. Lewis') opinion was to water the roads. Some of the gentlemen, who gave evidence before the Royal Commission, suggested that all roads, main ways, and gates should be watered on floor, roof, and sides. That precaution appeared to him to be rather unnecessary, and more especially so when, on reading the evidence, they were informed that the flame from a blown-out shot did not extend to more than 12 to 18 feet. He thought if the floor, roof, and sides were thoroughly watered for a length of 30 to 40 feet on either side of the shot, that safety would be ensured, and that no danger need then be apprehended from blown-out shots causing a coal-dust explosion.

Prof. ARNOLD LUPTON (Leeds) said that coal-dust was a most important and interesting question to mining engineers. Fortunately, pure coal-dust explosions were very rare, the conditions requisite for such explosions being seldom fulfilled, or few of the present company would have lived to be present on this occasion. They had gone about swinging flaming lamps in the dust, discharging powder into it, driving it to the furnaces, and in other ways unknowingly testing its explosive properties, and it had the good nature not to explode when they had been present, and therefore they had strong evidence of the non-explosiveness of coal-dust. But there were others who were not there who, if they were resuscitated, would be able to speak differently, who would tell them how powerful an explosive agent it was, that, indeed, there was no more terribly explosive mixture than coal-dust and air; and they would point out that its constituents were almost identical with those of gunpowder. They (the absent ones) had experienced how far-reaching were such disasters. As to the means of preventing these explosions, Mr. Lewis had pointed out that no mines in the country were safe from coal-dust explosions. There was dust in all, with the exception of the damp mines. The only way to destroy this explosive agent was to damp all dry mines, and the damping of mines was probably included in the word watering as suggested by Mr. Lewis. A mine was dusty because the heated ventilating currents sucked up the natural moisture of the strata. The better the ventilation, the drier would be the mine: the better the ventilation, the more explosive coal-dust would be prepared. If they did something to prevent the drying up of the moisture, they avoided the formation of dust. One

means of effecting this intent was by the use of spray jets, as adopted in many of the South Wales collieries, by which the atmosphere was saturated with a fine mist, and the formation of dust was prevented to a great extent. Warm mines were cooled by the system, and rendered more pleasant for the workmen, the damp prevented the rotting of the timber by dry rot, and possibly the expense of damping was more than recouped by the extra duration of the timber. Another advantage was that the water pipes might be used for watering the ponies, and this, besides being humane, might lead to a reduction in the cost of horsekeep. The more they understood the dangers that surrounded miners, the more they would guard against them. Credit, he thought, was due to mining and mechanical engineers, managers, officials, workmen, and H.M. inspectors of mines for the fact that, notwithstanding the great increase of production, there was a diminution in the death rate. A great deal of that diminution in the death rate was due to the greater knowledge of the dangers of fire-damp, which had enabled these to be counteracted and removed. The dangers of coal-dust had been generally recognized only recently; now the question was, how was this danger to be removed? He had no doubt that this recognition of the danger had already resulted in a great saving of life, and that in the near future the danger would be still further and greatly diminished.

Mr. A. Dury Mitton (Shipley collieries) remarked that the watering of roads in dusty mines did not last more than a week, owing to the water not penetrating through dust where it was very thick. When the water was first put on, it caused the road to be very slushy, and it had a great tendency to make the floor lift. He had found that common salt, costing from 8s. to 12s. per ton, could be used to very great advantage, as it penetrated through the dust, did not make the floor lift up, and produced a moistening effect in travelling roads (where some 300 to 400 men and boys and 50 to 60 horses and ponies passed daily) for at least six or eight weeks.

Mr. T. A. Southern (Derby) thought that whenever the subject of watering dusty main roads was mentioned, the systematic removal of the dust, so far as is practicable, not only from the floor, but also from the roof and sides, should be kept in mind, as being a very desirable precaution in conjunction with watering. He had recently made an interesting calculation to ascertain the quantity of water which might, under favourable conditions, be absorbed by the ventilation of a large, deep mine. And he found that under the conditions on which he based the calculation, no less than 170 tons of water might be removed from a

mine in this manner during twenty-four hours.* H
bear out what had been said as to the futility of
tinuously carried on. The result might appear s
incredible; but he might add that it was possible fo
without it forming, as might be thought, a tax up
ventilating fan and engine, because damp air is lig
the same temperature, and in fact the more vapou
saturation-point, at a given temperature, the less is i

Mr. H. R. HEWITT (Derby) remarked that o
very often asked by opponents of the coal-dust t
it that every blown-out shot occurring in dusty min
more or less disastrous explosion?" This questio
Royal Commission on Accidents in Mines, and the
Mr. W. C. Blackett in his able paper on "The Co
and Coal-dust in Mines."† Mr. Blackett says:—
conditions to be exactly fulfilled, that although eac
the whole combined are fortunately rare and diffic
must be enough spare power in the shot to stir up t
enough compression of air. The dust must be v
flame from the explosive must be of very high temp
able volume. Possibly the shape of the gallery, th
of the air, and the height of the barometer ma
Taken all together, the chances of complete coincid
we need not wonder at the rarity of the accident."
Bedson's investigations into this subject show that
are practically globules of inflammable gas, and it v

* A coal-mine, 1,800 feet deep, has a ventilating curren
air per minute. Suppose that on a damp winter's day, t
cast shaft is at a temperature of 33 degs. Fahr., and is sat
that the air when it leaves the upcast shaft is at 75 degs.
ted with vapour. If the volume of air above-named was
airways at 75 degs. Fahr. its volume when entering the
$250{,}000 \times (459 + 33) \div (459 + 75) = 230{,}337$ cubic feet

1 cubic foot of saturated air at 33 degs. Fahr. contains
1 cubic foot of saturated air at 75 degs. Fahr. contains 9
Mr. Glaisher's *Hygrometrical Tables*.) The weight of
air when it enters the mine is $230{,}337 \times 2{\cdot}2 \div 7{,}000 =$ 7
weight of vapour contained in the air when it leaves the
$7{,}000 = 335{\cdot}7$ lbs. per minute. The weight of water a
these conditions would be $335{\cdot}7 - 72{\cdot}4 = 263{\cdot}3$ lbs. per
minute, 1,580 gallons per hour, 37,920 gallons in twenty-
twenty-four hours.

† *Trans. Fed. Inst.*, vol. vii., page 60.

these particles should undergo the process of distillation to cause violent ignition. They had to face this danger, now that it had been pointed out by the report of the Coal-dust Commission, and he thought the best policy for all to adopt was to fall in with the suggestions there laid before them, and to become thoroughly converted to the newest phase of the coal-dust theory of colliery explosions.

Mr. G. E. Coke (Nottingham) agreed with what Mr. Hewitt had just stated, but he felt somewhat sceptical about the possibility of explosions occurring from coal-dust alone. He knew some very dusty mines where no explosions had occurred.

Mr. Reuben Allen (Tamworth) said his experience was that it was best to keep the places damp, but not too damp, because if too damp some of the roads would lift and cause great inconvenience. He constantly had water put on to the roads and sides, after loading up the thickest of the dust. This was done, at first, by lading water with buckets from a barrel, but it had since been found better to have perforated pipes encircling the bottom of the barrel with a pipe at each end connected with the barrel, and a tap in the pipes to turn on when required. Discretion must be used while watering, according to the nature of the floor and sides.

Mr. A. G. Barnes (Grassmoor collieries) said very often the cures suggested for a disease were worse than the disease itself. There are in Derbyshire some pits in which, if the main roads were watered, the effect would be to close the whole mine. The water would have such an effect on the road and the roofs that there would be continual falls, and if they continued to work in the mines under these conditions, the risk to life would very materially increase. This would be the case in many of the deep mines in Derbyshire—the blackshale especially. A better remedy, but an exceedingly difficult and expensive one, would be the sweeping of the dust, but in large pits this would be insuperably difficult and costly. The water remedy was the more facile where it could be applied, as it would be possible to ensure dampness throughout the pit, whereas the sweeping only removed the difficulty in one area. Where watering could be done without danger to the mine, it could be done at comparatively low cost.

Mr. William Hay (Burton-on-Trent) confirmed Mr. Barnes' statements. There was a very tender blue bind in one of the seams at the Stanton collieries, and if they were to impregnate the atmosphere with water, the danger from falls would be much enhanced. They would have to timber in some places every foot, in places where at

present timber was not used. In one district of this seam, the strata "bleed," and the roadways are in consequence always "fretting," and require timbering and constant attention; elsewhere the same seam is dry, and the roof of the roadways (some of which have been standing for many years) is perfectly sound, and timber is seldom required.

Mr. A. H. Stokes (Derby) was pleased to find that Mr. Lewis had read the report of the Royal Commission, and he would very much like to take a show of hands to ascertain how many young men present had also read it. Mr. Lewis stated that he (Mr. Stokes) advocated the abolition of all shot-firing, but Mr. Lewis should take the whole question and answer, as printed in the report.* His statement was, he thought, a clear truism, because if they never had flame they would never have explosions, and in that respect he thought his remarks were justified. He thought, after the explosion at Camerton colliery, that the days of gunpowder in dry and dusty mines were numbered, unless it could be used with water-cartridges or other contrivances, and so protected from igniting dust. This pit was situated in the Somersetshire coal-field, and he believed there was no record of any gas having been found in that coal-field for one hundred years, in fact as far back as the records extended. He was down the pit in the company of two experts with the most delicate apparatus for testing the presence of gas to as small a proportion as ½ per cent., and although they tested the air before the ventilation was restored, they could not find a trace of gas. The whole ventilating current of air was cut off from the district where the explosion occurred for a fortnight, and another test made, but no gas found. No gas had been detected since, and none before. Consequenty, there could be little doubt that the Camerton explosion was a coal-dust ignition. It was caused by a powder shot, and probably such a shot as no one there present would sanction being used. The hole was 10 inches deep, charged with ½ pound of powder, and was intended to blow down about 8 inches of material, and he thought that the workman would have got it down more easily with a hammer and wedge. The Mines Act stated that if a place where a shot was to be fired was dry and

* 3069.—That shows that mere watering is not a sufficient remedy?—The remedial measures must not be dependent upon watering, and the remedial measures must not be so much in depending upon the removal of the dust. The removal of the dust certainly—if you could remove it—would be effectual, but practically that never could be done, and I am afraid watering cannot be effectually done. The remedial measures must be looked for in the initial start of the explosion; stop the explosion, stop the shot-firing, stop the gas explosions, and you need not take any notice of dust so far as colliery explosions go. But certainly I would suggest that watering is of value for the health and comfort of the men, as regards the purity of the atmosphere which goes into the mine.

dusty it was necessary that the roof, floor, and sides should be watered. He did not know whether that was fully carried out all through his inspection district, and that the top, sides, and bottom were watered before shot-firing in dry and dusty places. In Great Britain, there were probably 20,000,000 shots fired in a year, and it was somewhat curious that there were so few ignitions of dust. As regards the removal of the dust, if they selected a roadway, a large intake roadway, and that was generally the haulage one, and attempted to remove the dry dust, he fancied that of every shovel taken up a good part would be blown away by the strong air-current, to be deposited again in another part of the roadway. If the top and sides were swept with a besom, it would be in a great measure transferring the fine dust from one place to another. The heavy portion might be removed with advantage, but the very fine and most dangerous dust would require special precautionary measures. If a large tub of water were taken, and the water allowed to run down the middle of the roadway, it would become muddy for a short distance, and only for that short distance would the watering have any effect. Some of the most efficient watering was done in the South Wales collieries. The atmosphere in the main roadways was saturated with spray, so much so that the man who travelled with the train of tubs had to change his clothing twice daily. On examining a pile of dust, he found that there was a damp film on the top, but the dust was dry underneath, and although the air was quite saturated with moisture, yet the dust in the man-holes was dry, and easily blown into a dense black cloud. Remedial measures must in a great measure have reference to shot-firing, gas, and lights. In mines, where there was tubbing, it was easy to take a pipe down the shaft and utilize the water-pressure for spray-watering of the dusty roadways. For sanitary reasons, the use of sprayed water was of distinct advantage, and, if judiciously done, it would not have the effect that Mr. Barnes feared.

Mr. T. A. Southern said he should like to be clear as to Mr. Stokes' reference to watering in a main haulage-road before firing a shot. He thought Mr. Stokes appeared to lightly regard that provision of the Mines Act, and to suggest that he would countenance disregard of it. He (Mr. Southern) had always considered that portion of the general rule to be one of the most important precautions against the dangers of coal-dust. This was certainly the view held by mining engineers in South Wales, and also, he thought, in other districts. Many of the most serious explosions had been connected by strong and well-established evidence with blasting on main haulage-roads, that was to say roads in which the

coal was hauled by mechanical power. He understood Mr. Stokes to say that the Camerton explosion was caused by blasting in a main haulage-road which had not been watered. Such a fact was strongly in favour of the general rule being enforced. Probably, if the place had been thoroughly watered, the explosion would not have occurred. The long immunity from any serious explosion which the Midland inspection district had fortunately enjoyed, and which he hoped would long continue, might lead some of them to regard this matter lightly, but he thought it should be treated seriously. The danger was ever present, and at any moment they might be only too unpleasantly and forcibly reminded of it. He hoped that his impression of Mr. Stokes' view of this part of the general rule was not what he (Mr. Stokes) meant to convey, but he had fancied there was a tendency to suggest a general non-observance of what he considered to be one of the most valuable rules in the Mines Regulation Act of 1887, and one which he thought should be most strictly complied with. The conditions to which this section of the general rule applied were very clearly defined, viz., a dry and dusty place, forming part of a main haulage-road or being a place contiguous thereto, and showing dust adhering to the roof and sides. These conditions might exist in any mine, even in one which would not be described generally as a dry and dusty mine. It was not every day that shot-firing was required in a main haulage-road, and compliance with this rule, by removal or watering of the dust, was not a very costly or, in view of the danger, an unnecessary requirement.

Mr. Stokes said that, in his opinion, if the roof, floor, and sides within a radius of 60 feet of the shot at Camerton colliery had been in a wet state from thorough watering, there would have been no ignition of the dust. He wondered how many gentlemen insisted upon the roof, floor, and sides of a dusty place being in a wet state with thorough watering for a radius of 60 feet before a shot was fired?

Prof. Lupton: All.

Mr. Stokes said that the next question would be: What is a dusty mine?

Prof. Lupton enquired whether Mr. Stokes, in speaking of blasting, referred to gunpowder blasting or to blasting with any other kind of explosive?

Mr. Stokes replied that he referred to gunpowder blasting alone. He found that rather than go to the expense and trouble of thorough watering in the way described, managers used the high explosives which were supposed to be of such a nature as not to inflame dust, and in some

places water-cartridges were used. There was another point with respect to gunpowder that appeared worthy of consideration, in cases where compressed powder was used: a shot was put in a roadway with 4, 5, or 6 bobbins of powder and a fuze at the end of the one first inserted in the hole. The questions he asked were—whether the whole of the powder was consumed before the material or ramming gave way, or whether some portion of the charge was sometimes blown out into the roadway in an incandescent state, to be finally consumed by the atmosphere after leaving the hole?

Mr. A. G. BARNES said his contention was that the mere damping and saturating of the air would have the effects which he had pointed out. The amount of water would not in effect make any appreciable difference; if it were mixed with the air at all it would get into the roof and sides, and continual falls would ensue.

The PRESIDENT said that salt was, no doubt, a very cheap article, but he dreaded, in the present condition of the coal trade, any addition being made to the cost of working. He thought they were all, practically, of one opinion except as to the effect, on the floor, of watering as mentioned by Mr. Barnes. He agreed with the evidence given by Mr. Stokes before the Royal Commission. In every case where there might be danger, flameless explosives were used in the mines under his charge. He agreed with previous speakers that to cause a coal-dust explosion they required such a combination of circumstances as very seldom arose. They already knew much of the effect of gas, and provided accordingly, and they now knew a great deal of the properties and the dangers of coal-dust, and to be forewarned was to be forearmed. He did not wish to ignore the possibilities of an explosion of coal-dust, but he thought, if they read carefully through the evidence laid before the Royal Commission, that they would find, most of them at any rate, no particular cause of fear. The great point was to use a practically flameless explosive. It had been given in evidence that there was no absolutely flameless explosive. He dared say there was not, but he thought for all practical purposes there were several. He was using ammonite, etc., where considered necessary, instead of gunpowder.

The discussion was then adjourned.

DISCUSSION UPON MR. DEACON'S PAPER ON "THE USE OF EXPANSION-GEAR AS APPLIED TO COLLIERY ENGINES."*

Prof. ARNOLD LUPTON (Leeds) said that the paper was a valuable record of facts observed, and experience gained as to the use of expansion-gear. The advantages of the expansive use of steam were chiefly apparent when they had high pressure, and to have the full advantage of expansion they must have high pressure in all non-condensing engines. If they had the steam at atmospheric pressure in a non-condensing pressure-engine, it was absolutely useless; increase the pressure to 5 lbs. and it would be just enough to overcome the friction of the engine, but there would be no useful work done, because the total average effective pressure was only just equal to the opposing pressure of the atmosphere and the friction of the engine. So they must have 5 and 15, or a total absolute pressure of 20 lbs. before they obtained any useful effect. If they doubled the pressure, they got 50 per cent. of mechanical effect; if they went to 60 lbs., they got 66 per cent.; with 80 lbs., 75 per cent.; and with 100 lbs., 80 per cent. of mechanical effect. If they applied expansion-gear, the average steam-pressure would be less whilst apparently economizing the weight of steam used per indicated horse-power. The mechanical effect was reduced by reducing the average effective pressure. But the average effective pressure should not be greatly reduced. By cutting off at half-stroke, the average effective pressure throughout the stroke was not much reduced, therefore a cut-off at half-stroke with steam at 60 lbs. pressure could be applied with great advantage. If the steam was cut-off at quarter-stroke, the average effective pressure was so reduced that they nullified the apparent advantage shown in an indicator-diagram. There was also a collateral advantage of expansion—that of getting rid of the steam at the end of the stroke without back pressure, which was a great one.

Mr. ALFRED DAVIES (Burton-on-Trent) said that the adoption of expansion-gear on large winding, pumping, fan, and other engines was not general, and there was still room for great improvement in this direction. He had obtained a number of indicator-diagrams from the engines at a large colliery, when the management passed into fresh hands some little time ago, with a view to the discovery of the causes of excessive consumption of coal at the colliery. These diagrams clearly indicated that

* *Trans. Fed. Inst.*, vol. vii., page 672.

the engines generally were very wasteful of steam, and as the surface-plant and machinery were designed and remain under the special supervision of a qualified mechanical engineer, he thought that much better results might have been expected. If efficient expansion-gear were applied to these engines, the economy resulting therefrom would be very great. In several instances the cylinders have not been made proportionate to the work to be done, some being too small and others excessively large. An instance of the latter fault occurred in a fan-engine working in the same district: the cylinder was 32 inches in diameter, and fitted with expansion-gear; the fan and engine could be run at the normal speed with the stop-valve almost closed and an early cut-off. A liner (24 inches in diameter) and condensing apparatus were applied to the engine, and gave most economical results. In another case, where the cylinder was too large, the engine was compounded by the addition of a high-pressure cylinder, fitted with expansion-gear, and great economy resulted from the alterations. In both these cases the pressure of the steam remained unaltered. The indicator-diagram, Fig. 6, Plate XIX.,* although it shows a good expansion-curve, proved that if the cylinder had been less in diameter, the steam might have been carried farther through the stroke, and losses by condensation and subsequent re-evaporation due to too early cut-off would then have been prevented. The indicator-diagrams, Figs. 1 and 2, Plate XIX.,* are interesting as experiments; they prove that great economy of steam cannot be expected from linking-up the valve-motion, because the valves have less lift and do not benefit by the small increase of lead caused by linking-up. The effect of linking-up is very great in locomotives where the length of the eccentric rods is short in proportion to the travel of the valve. The diagrams, Figs. 3 and 4, Plate XIX.,* show the evil effects resulting from contracted passages and small valves, largely reducing the capacity of the engine, and requiring the use of a large cylinder where a smaller one would otherwise have been sufficient. The effects of small thoroughfares are illustrated in Figs. 1 and 2, taken

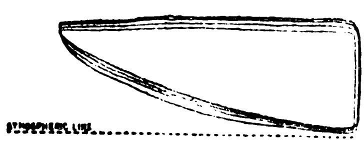


Fig. 1. Scale $\frac{1}{32}$.

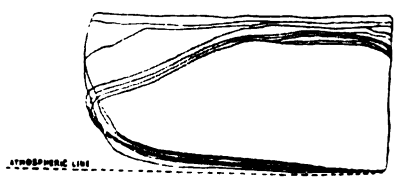


Fig. 2. Scale $\frac{1}{32}$.

from a horizontal winding-engine, with 2 cylinders, each 36 inches in diameter and 6 feet stroke, fitted with a drum 22 feet in diameter, and

* *Trans. Fed. Inst.*, vol. vii., page 684.

raising coal from a depth of 1,344 feet. The diagram (Fig. 1) shows the action of the steam in the cylinder, with valve-gear as fitted by the engine-builders. The diagram (Fig. 2) shows the improvements effected after new valve-boxes and expansion-gear had been fitted by Messrs. Thornewill & Warham. The quantity of coal drawn to bank was increased from 200 to 250 tons per day, and although the valves still required slight adjustment, the winding-engine had raised 1,280 tons of coal, 200 trams of rubbish equal to about 300 tons, or, in all, nearly 1,600 tons per day of 9¾ hours. Three tons of coal are raised at each winding; the quickest winding has been done in 39 seconds, being from 8 to 10 seconds quicker than the best time recorded previous to the alterations. This example shows that, even with contracted branches on the cylinder, much improvement may be made by increasing the area of the valves and enlarging the thoroughfares in the valve-boxes. The Guinotte expansion-gear will appear complicated to every practical man, and the very few gears of this type that have been fitted afford sufficient evidence of this fact. The expansion-gear made by Messrs. Thornewill & Warham has been applied to 9 winding-engines, having cylinders varying from 18 to 42 inches in diameter, and in each case it has been successfully and advantageously applied. When a mining engineer entertains the idea of fixing expansion-gear to a winding-engine, the question arises whether the change will be economical, and although the depth of the shaft may not be a factor, the number of revolutions per winding will necessarily be one in deciding upon the change, as in order to secure economy the gear should be in action not less than one-half of the number of revolutions in each winding. If the product of the area of the cylinder in square inches, of the steam pressure in pounds per square inch, and of the length of the crank in feet is equal to, or greater by 2½ or 3 times than the product of the nett load raised in lbs. and the radius of drum in feet, the adoption of expansion-gear is desirable. An engine with these proportions will be able to raise the load sufficiently rapidly, the cut-off may come into action after the third or fourth stroke, and the mean pressure required in the cylinder will be obtained with a cut-off of less than half-stroke. Mr. Deacon states that a "decreased speed of running" is the inevitable result of the use of expansion-gear. This statement may be true in some cases, but the example of increased speed of winding already referred to shows that, with suitable valve arrangements, combined with good expansion-gear, this difficulty may be overcome. The governor is not intended to regulate the speed of the engine in the same sense as is understood in connexion with, say, a mill-engine, but is simply an instru-

ment intended automatically to put the cut-off in operation without particular reference to the rate of expansion, but adjustments of the gear can be made so as to prevent decreased speed of winding when the cut-off gear is in action. He hoped that Mr. Deacon's paper might have the effect of drawing attention to the unsatisfactory state of the engines at many collieries, so that the same efficiency of surface-plant may be found in Great Britain as obtains on the Continent, where recently he had the pleasure of seeing some very fine and well-kept collieries which would compare very favourably with the best in this country.

Mr. ROBERT THORNEWILL (Burton-on-Trent) remarked that a saving of 25 per cent. of fuel was also a saving of 25 per cent. of boiler power. If, for instance, four Lancashire boilers were in use, by applying expansion-gear three might be sufficient, and in putting down new plant a considerable saving might be effected. Taking the cost of the automatic expansion-gear at £100, the cost of a boiler, including the brick-seating, would not be less than £300, and a saving of £200 could be realized.

Mr. H. R. HEWITT (Derby) said that the mechanical appliances described by Mr. Deacon were worthy of much more attention than had up to the present time been devoted to them, as the consumption of fuel would, if trade revived, be a serious item in the colliery cost-sheet. He noticed that in some types of expansion-gear it was necessary to have a steam-reverser, which would probably waste the greater portion of the steam saved by the automatic gearing being applied to the valves, so that in those cases the ultimate saving of fuel would be very little. The loss of 4 seconds of time in a winding of 33 seconds, from a depth of 684 feet, will probably be viewed with some apprehension by mining engineers, who contemplated giving their workmen a shorter working-day at some future date.

Mr. A. DAVIES said that when the expansion-gear was in action the speed of winding was not necessarily decreased, if the gear were properly adjusted and the valves and passages made of ample capacity.

The discussion was then adjourned.

Mr. H. R. HEWITT read the following paper on "An Underground Endless-rope at the Moston Colliery, Manchester":—

AN UNDERGROUND ENDLESS-ROPE AT THE MOSTON COLLIERY, MANCHESTER.

By H. RICHARDSON HEWITT.

The subject of underground haulage has received a considerable amount of attention from this Institution, and it is because the circumstances under which this rope is working are rather exceptional, that the writer feels impelled to give an account of it.

This endless-rope is in operation on an incline-plane or down-brow, driven nearly on the full dip of the big mine coal-seam, the thickness of which is 6 feet when measured at right-angles to the dip of the strata.

The incline is now 2,900 feet long, and the rope under notice is at present working upon a length of 2,280 feet, drawing the coal uphill from the several landings, the lowest of which is 2,100 feet down the hill, and hauling the same to the main level upon which another endless-rope is running from other incline-heads to the pit-bottom, passing this one on its way, and conveying the coal to the shaft.

Fig. 1, Plate XXI., illustrates the inclination of the road, which dips from 26 degs. to 39 degs., although the actual inclination at the several landings is 45 degs., owing to the floor having been taken up to allow of the rope-road passing under the level landings. The present extent of the working rope is from *A* to *B*, a length of 2,280 feet, and some idea of the work to be done will be observed from the fact that the terminus wheel at *B* is 1,260 feet in vertical depth below the landing at the top of the incline.

The rope is 1⅛ inches in diameter, and was started on March 24th, 1891. This is the second rope which has been put on, and has now been at work for over three and a half years. It is working for nine hours per day, although during the first twelve months of its life it was running for eighteen hours per day, as two shifts per day were, during that time, being worked. The first rope was in every way similar to the present one as regards manufacture and diameter, and worked continually for eighteen hours per day. When it had been on two years it was con-

sidered advisable to replace it, because it had been subject to much rough usage, as every person connected with its inauguration was quite inexperienced as to the class of work it had to perform. Now that the officials and workmen are quite accustomed to their duties, the present rope runs perfectly smoothly and without vibration, and will to all appearances work for some considerable time longer. In speaking of the running of the rope, the management has always had this essential feature in mind, because, with the exceptionally heavy gradient, the risk entailed in the event of a clip becoming loose was greater than in a mine with a lighter gradient.

The average quantity of coal hauled per day of nine hours is 300 tons. Members of a critical turn of mind may not consider this to be an exceptional case, but in view of the exceedingly heavy inclination against the loaded trams, the writer will enter into details as to the actual strain upon the rope in question. This $1\frac{1}{8}$ inches diameter rope is 3·534 inches in circumference, and the breaking strain of a rope of this description, when made of the best possible materials, is 52·83 tons. The greatest angle of inclination of the road is 45 degs., and this angle should be taken in calculating the present working-load. The stress on the rope for each ton of load is 1,609 lbs., allowing 25 lbs. per ton for rolling friction. The weight of an empty tram is 4·5 cwts., the average weight of coal which it contains is 10 cwts., and the number of trams on the rope at one time is 36, 18 of which are coming up full, and 18 are going down empty, so that there is a load of over 17 tons continually moving with the rope, 9 tons of which is not balanced, and the full rope is pulling a load of over 13 tons. The weight of the rope is 4·325 tons, so that the total moving weight is over 21 tons.

There will be very little friction caused by the rope and trams working on the empty side, and taking the total weight on the full side, viz., 13 tons $\times$ 1,609 lbs. $=$ 9·3 tons as the equivalent pull in a vertical direction. The weight of the rope on the full side is 2·162 tons, and 2·162 $\times$ 1,609 lbs. $=$ 1·5 tons as the equivalent weight of the rope when pulled vertically, and 9·3 $+$ 1·5 $=$ 10·8 tons as the equivalent total load when pulled in a vertical direction. As the theoretical breaking strain is 52·83 tons, it will be readily understood that this rope is doing more than its proper share of work, the working load being, from the foregoing, $\frac{1}{5}$th of the breaking strain.

The full trams are attached singly, and the empty ones are sent down in pairs. Both the attaching and detaching of the trams are done at all points without stopping or interfering with the speed of the rope, and it

is a common occurrence for the rope to be continually moving all day at the regular speed without being stopped from any cause. Electric signals are carried throughout the length of the incline.

The rope travels at the rate of 7,800 feet per hour, and runs under the tubs, which are attached to it by means of a stout parallel-jaw clip. The jaws of the clip are actuated by means of a screw and hand-wheel, and a hinged bar 2 feet long serves to connect it with the draw-bar of the tram. This iron bar prevents the clip from turning round and fastening itself under the rollers between the rails, and is also necessary in assisting the tram to keep the rails when being attached to the rope at the time of leaving the level-landings. The jaws of the clip are made to a radius of 3½ feet, so that when the screw is tightened the clip has a firm grip of the rope in at least three places, namely, at either end and in the centre. This shape was found to be absolutely necessary, as when the ordinary clips were used the full trams would occasionally break away and slip down the rope when nearing the top of the incline. This was caused by the full rope being of slightly less diameter at this point, owing to the increasing tension when nearing the top. The thinnest part of the rope is at the point where it is entering the flanges of the driving pulley at the top of the incline, and this will explain why all ordinary clips frequently failed to deliver the full trams on to the main level.

There are several intermediate landings at which the full trams are attached to, and the empty ones detached from the rope, so that an explanation of one of them will suffice for all. Fig. 2, Plate XXI., represents a tram being either taken off or placed upon the rope, and Fig. 3, Plate XXI., shows a tram passing the landing. Sufficient roof is taken down to allow one full or empty tram to stand on the fixed landing *A B*. There is a movable hinged landing *A C*, controlled by a balance-weight in such a position that when it is lowered, the empty trams will run on to this platform instead of going farther down the hill. Immediately the trams have arrived at the movable landing, the clip is unfastened, and they are run on to the fixed landing *A B*, and the movable landing *A C* is immediately pulled up by means of the balance-weight into the position shown in Fig. 3 until it is required again. The trams are then pushed into the levels on either side of the incline wherever they are required. When a full tram is about to be clipped on to the rope, the movable landing *A C* is lowered, and the tram is brought on to it, as shown in Fig. 2, and, without stopping the rope, it is clipped and started up the hill. The full trams are at once put from level to incline without any intermediate lesser gradient, and so are the empty ones. A very little

space is taken up in the attaching and detaching of trams, and the hinged platform is balanced so as to just lift after the weight is off. Two youths, paid 3s. per day each, are sufficient to attend to each landing.

The power which works this rope, along with others, is transmitted from the surface by means of an endless-rope to a central station underground. This strap-rope passes uncased down the upcast shaft, and is actuated by a compound condensing engine, with high and low pressure cylinders, respectively 15 inches and 25 inches in diameter and 4 feet stroke, and the ratio of speed is as 14 of the engine is to 1 of the incline hauling-rope. The engine, besides working the incline, hauls coal along the main level, which is 2,850 feet long, and also runs three endless-ropes on the surface, which do the shunting of railway-trucks below the screens.

At the underground central station an upright iron shaft is fixed, to which are attached three pulleys, only one of which is keyed on to the shaft. It is this pulley which receives the power from the surface, and transmits it to the other two pulleys, one of which works as a strap-rope for this incline, and the other works the main level. The general arrangement of this central station is seen in Fig. 4, Plate XXI. The main pulley is 10 feet in diameter, and the other two are each 7 feet in diameter, so that the ratio of speed is as 10 is to 7. One of the 7 feet pulleys works the endless-rope under notice, and it is thrown in and out of gear by means of the Fisher friction clutch-gear. All the pulleys are inclined on the rope-surface to the extent of $1\frac{3}{16}$ inches in 6 inches, so as to cause the $2\frac{1}{2}$ turns of the rope (which are necessary to give the proper grip) to be constantly surging in the direction of the lesser diameter. It is very necessary that this movement should be uniform, especially when it is required to haul from so steep a gradient, as in this case, or serious damage would be the result.

Each rope, excepting the incline-rope, has a separate tightening arrangement at the central station. The tension-carriages are either placed on rails in dip-roads where the gradient is steep enough to give sufficient tension without any weight other than the weight of the carriage itself, or are working on level-roads with balance-weights attached by means of chains passed over pulleys. Notwithstanding the heavy load, the movement of the tension-carriages is only slight, usually 3 or 4 inches, and the elongation of the rope, even when put on new, is never more than a few feet. Care is taken in every case to put tension on to the empty side rope only, *i.e.*, on the "coming-on" side, and not on the "pulling" rope at the vertical shaft, in the case of the main strap-rope from the surface.

It will be noticed in Fig. 4, Plate XXI., that on the pulley working the incline-haulage, a brake-rim is cast and faced with steel segments. Upon this braking-surface four steel slipper-blocks rest, and are set at such an angle to the diameter of the wheel, so that upon the incline-rope being thrown out of gear, the pulley is arrested from a backward tendency. This automatic brake-arrangement only comes into action when the pulley is liberated from the grip of the friction clutch-gear. A duplicate of the arrangement is placed at the top of the incline, as shown in Figs. 5 and 6. The 7 feet pulley runs within a square timber frame, and from the centre of each baulk a cast-steel block is suspended by means of a toggle joint, in such a position that when the wheel is revolving in the proper direction, as shown by the arrow, it just clears the brake-rim of the wheel; the blocks are further kept in position by means of very light spiral springs. When the pulley is thrown out of gear its first impulsive movement is to revolve in a contrary direction, caused by the hanging weight in the incline, but this is immediately arrested by the automatic blocks coming into action.

Fig. 7, Plate XXI., is a sketch plan of the arrangements between the central station and the incline and level return-wheels respectively. At the bottom of the incline a return sliding-wheel is placed, and it is not necessary to attach a weight to this wheel, as it is found that the weight of the rope in the incline always gives sufficient tension to keep it taut.

The incline-road is laid with a double line of rails throughout. Steel rails weighing 24 lbs. per yard are used, with fish-plates at the joints. The rails are each 9 feet long, and one steel sleeper is used for each pair, of sufficient length to allow of its being cut and plugged into the solid side of the roadway, to prevent the road from slipping down hill, and to keep the gauge permanent. Wooden sleepers are placed at intervals of 3 feet between the steel ones, and steel rollers 6 inches in diameter are fixed between the rails at intervals of 36 feet.

Previous to the endless-rope being started, the coal was brought up the incline by a main single rope, worked by a pair of compressed-air engines fixed at the top of the incline. It is now found that the working cost of the new system is one-quarter that of the old, and has, therefore, even exceeded the most sanguine anticipations.

The weight to be attached to one rope working under these conditions is limited, and the successful working of this rope under very difficult conditions leads the writer to the opinion that it is quite possible and also practicable to run two or even three ropes in the same road, and between the same lines of rails, and attach the trams to each rope in turn.

It is simply a question of power, and by that means the question of haulage in seams with heavy gradients may be overcome.

The whole arrangement has been carried out by the manager, Mr. Thos. Greensmith, who deserves every credit for bringing this very awkward matter to a successful issue. Mr. Greensmith has experimented on a large scale to arrive at the above general arrangements, and has succeeded in a remarkable degree in bringing this coal out with a maximum degree of safety, and at a minimum cost.

Mr. G. J. Binns (Burton-on-Trent) said that Mr. Hewitt had written a most valuable, practical paper. The haulage-system had apparently been carried out under very great difficulties. The clips seemed to be very similar to one that he had seen in use on cable-tramways.

Prof. Arnold Lupton (Leeds) said that Mr. Hewitt suggested two or three ropes as being preferable to having one very heavy one. He supposed this suggestion was made in view of a much longer one being required in case the incline was lengthened, so that the No. 1 trams could first be put on to No. 1 rope, No. 2 trams on to No. 2 rope, and so on. The paper was most interesting, not only for underground haulage, but for the transmission of power by wire ropes, similar in principle to a system of transmission which he (Mr. Lupton) had erected in North Wales some years ago. Considering the great strain on the haulage-rope, it showed what could be done by wire-rope transmission of power, and the great economy that could be effected by its use. He thought that the paper was a most valuable contribution to the *Transactions*.

Mr. Edward B. Wain (Stoke-upon-Trent) said some of the members possibly were aware that the work was carried out under the supervision of the father of the author of the paper, the late Mr. J. R. Hewitt. Although there were exceptional difficulties in installing endless-rope haulage under such circumstances, the work had been an unqualified success, and the manager of the colliery had recently assured him that it was by no means uncommon for the rope to work for the whole of the day without being stopped from any cause whatever. The paper must be peculiarly interesting to the members of that Institution, as the most important parts of the plant (the friction-clutches and safety-brakes) were the invention of one of their members, Mr. Fisher, of Clifton; and the general arrangement is on the lines suggested by that gentleman in section III. of his paper on "Endless-rope Haulage."* He (Mr. Wain)

* *Trans. Chesterfield Inst.*, vol. xii., page 148.

was of opinion that there was no more suitable apparatus for haulage against such a heavy load than the Fisher-Walker friction-clutch and safety-brakes, and he had recently erected a plant to work under somewhat similar conditions with an average load rather in excess of that at Moston collieries, but with an easier gradient. In the Midland district, with the mines lying horizontally, or nearly so, they would perhaps hardly appreciate the difficulties in haulage in highly inclined seams. In the North Staffordshire and Lancashire districts, where the measures lay at 20 to 80 degs. from the horizon, the appliances required for haulage had to be even better than those used at the winding-shafts, and particularly where, as at Moston collieries, the whole of the coal had to be hauled from the deep. As an illustration of this fact, they might compare the plant referred to in Mr. Fisher's paper with that described by the author. In the former case an engine with two cylinders, 22 inches in diameter and 2 feet stroke, geared 6 to 1, was able to deliver 1,200 tons per day of eight hours, whilst in the case described by Mr. Hewitt a compound condensing-engine, with cylinders 25 and 15 inches in diameter and 4 feet stroke, geared 14 to 1, could only haul 300 tons per day of nine hours over a much shorter distance. The chief difficulties in starting such a plant were the angle of inclination on the rope-surface of the surging-wheels and the means of attachment of the tubs to the rope. The angle of the rope-surface could only be decided by experiment in the case of such heavy loads, and he believed that no rule and no amount of experience in such matters could decide what was the most suitable angle to suit each case. He had a case in mind where wheels with a given angle worked perfectly with a given load; but in another case, where the load was, almost exactly the same, 50 per cent. less slope on the rope-surface of the pulley was required. The clips described by the author had been found to work fairly well in the particular case described, but he believed that it was necessary to keep a boy in the dip near the top to tighten the clips as they passed. The author had called attention to the fact that the increasing tension on the rope made it of appreciably less diameter at the top of the brow and the curve in the jaws was necessary in order to "hitch" the rope and counteract the tendency of the clips to slip. Very great care was necessary in screwing on the clips, and considerable force had to be applied to deflect the rope to such an extent so as to make it lie between the curved-faces of the clip-jaws. Although he (Mr. Wain) was using similar clips under somewhat similar conditions, he was not satisfied that they were absolutely reliable. He was of opinion that a clip should be used which had some compensating movement that would

allow the grip to tighten as the weight on the rope below it increased, and it consequently became smaller in diameter. This might be effected by making the attachment between the loaded tram and the clip at some point on which the weight of the load would be thrown, so as to supply the increasing tension when required, or to hold the jaws close to the rope whatever its diameter might be under the varying load. He did not quite agree with the author as to the desirability of working two or more ropes in the same road between the same lines of rails and attaching the trams to each rope in turn, so as to divide the load. Where the load was too great for a rope of reasonable dimensions to be used, he should prefer to divide the load by using one rope so far as a fair margin of strength would allow, and driving the lower portion of the brow by means of a belt-rope running on the side of the road to the station to which the first rope was worked. The advantages of such a plan would be that the length of rope, as compared with the plan advocated by the author, would be reduced, and that the old ropes on the first length might be worked as belt-ropes for the lower section, after they had been rejected for the heavier work of hauling.

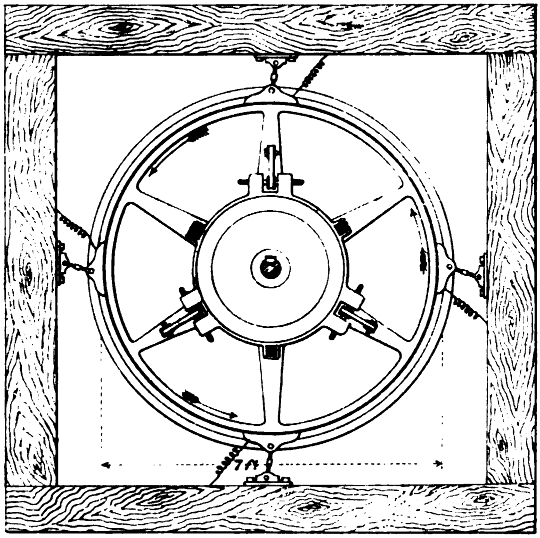
The President proposed a vote of thanks to Mr. Hewitt for his valuable paper. Next to the saving of men's lives, the subject of economy in working was most important.

The resolution was carried unanimously, and the discussion adjourned.

THE WOOD PISTOL SHOT-FIRER.

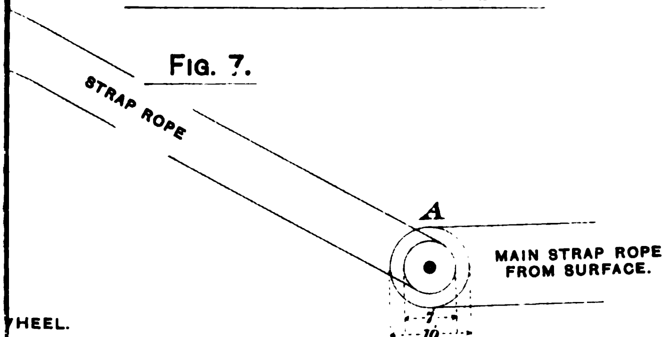
Mr. Reuben Allen (Tamworth) stated that the length of fuze required was 9 inches, which was inserted about 4 or 5 inches into the shot-hole. One end of the fuze was placed in a tube filled by the colliers with loose powder and brought by them to the mine. When the shot was ready for firing, the deputy after he had examined and found the place to be safe, put a cap into the shot-firer and inserted the fuze in its open end; he then pulled the trigger, removed the shot-firer, and went away until the shot was exploded. Formerly when the shots were ready for firing, the deputy, after the place had been examined, fired the shots by means of Bickford and Smith shot-igniters fixed on the end of the fuze, and crushed by a pair of nippers. A halo was sometimes seen when these igniters were crushed. The number of shots fired in the mine by the shot-firer was 85 per day, 425 in five days, or 21,250 per annum. The Bickford and Smith igniters used cost about £73 per annum. The

FIG. 6.



ARRANGEMENT OF BRAKES AT CENTRAL UNDERGROUND STATION AND AT TOP OF INCLINE.

FIG. 7.



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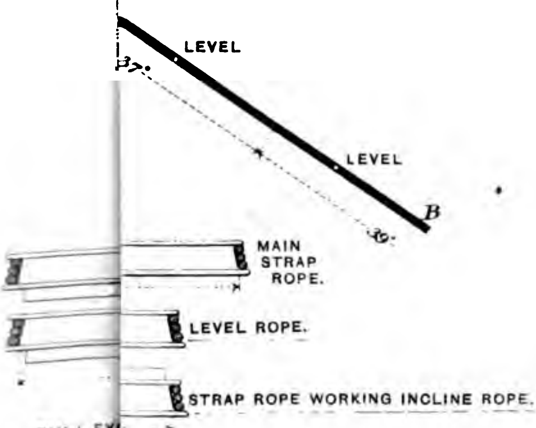
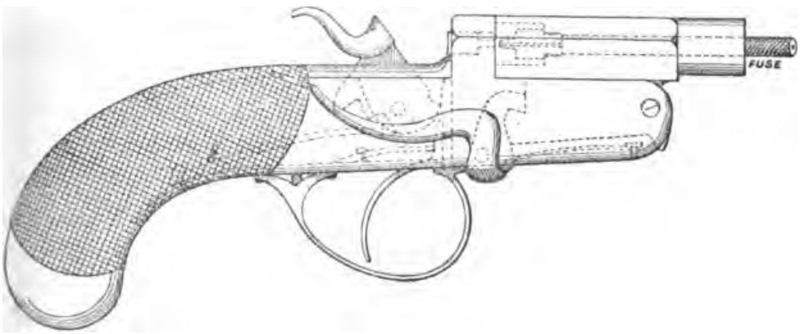
WHEEL.



PULLEY

Chesterfield and ... ENTRAL

caps for the shot-firer only cost £2 2s. 6d. per annum, a saving of £70 17s. 6d. per annum. The shot-firer cost £1 8s. 6d. each and repairs had cost about £2 10s. per annum. There was no appearance of fire (only sparks) when the cap was struck, if it had been closely placed upon the nipple.



Mr. Allen, in reply to questions, said that the fuze was never pulled out by the pistol. The pistols were used in districts where safety-lamps were in use.

Mr. J. W. Barlow (Chesterfield) failed to see any difference in point of safety between lighting the fuze with the pistol and lighting it with a shot-firing wire in the usual way.

Mr. H. R. Hewitt asked whether the pistol shot-firer was safer than firing with an electric detonator?

Mr. J. Wood (the inventor) said that the pistol shot-firer could be safely used where gas was present. It was fire-tight and gas-tight.

Mr. Hewitt remarked that the sparks might ignite gas or anything else.

Mr. Wood remarked that the shot would ignite gas.

STIRLAND SAFETY CAGE.

Mr. J. Stirland (Marlpool, Derby) exhibited a working model of a safety-cage apparatus for use, with wire conductors. Levers are so arranged as to cause the cage to stop the instant the rope is severed, and this is effected without the possibility of a sudden jerk, springs being provided to form a cushion and buffers to press the end of the levers, so that the heavier the cage the firmer would be the grip on the wire guides. In case of the rope breaking, there would be very little delay in re-

starting, as there was no jamming or tight wedging; the moment the bull chains are tightened, the clutches were released without damage to the conductors. All the parts of the apparatus are clear of the guides when the cage ascends or descends. The apparatus does not grip the conductors when on the props, either at the top or bottom of the shaft, as there are self-acting rods at the end of the chain, which are applied as soon as the cage rests on the props. The apparatus could at any time be tested without detaching the rope from the cage.

HORSE-FEEDER.

Mr. G. H. W. ALDERSON (Chesterfield) exhibited an automatic horse-feeder, designed to give feed to horses at early morning and other times, in the absence of the groom or other attendant. In the carrying out of this object, an ordinary alarum-clock is provided and utilized. The clock is set, so that the alarum-gong will be struck at any desired time, the mechanism provided to release the alarum-gong hammer also releasing a gravity-hammer, *i.e.*, a hammer that falls by its own weight when released. The gravity-hammer, after it has fallen from the raised position, strikes the head of a vertical sliding-bar and releases a cam, the release of such cam setting free a weight at the end of a feed-box or boxes, from which the feed thereupon slides and falls into the manger. When the automatic or alarum movement has released the feed-box or boxes, the automatic movement can be re-set by turning the handle of the cam to the left, until the notch provided in the cam makes connexion with the lever. The gravity-hammer is then lifted into the set position as at first.

The meeting terminated with a vote of thanks to the President, who expressed the acknowledgments of the members to the exhibitors, and to the authorities of the borough of Derby for the use of the room in which the meeting had been held.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE ODDFELLOWS' HALL, KILMARNOCK, DECEMBER 8TH, 1894.

MR. GEORGE A. MITCHELL, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentleman was elected by ballot :—

FEDERATED MEMBER—

Mr. JAMES MILLER HEAD, Glasgow, Rhea County, Tennessee, U.S.A.

DISCUSSION ON MR. R. FISHER'S PAPER ON "THE COAL-FIELDS OF LABUAN, BORNEO." *

Mr. FISHER wrote that antimony had not been found in Labuan, the specimen produced being from Borneo.

The discussion was then closed, and a vote of thanks accorded to the writer of the paper.

DISCUSSION ON MR. F. J. ROWAN'S "HISTORICAL NOTES ON EARLY PLANS FOR COAL-WASHING." †

Mr. BARCLAY stated that he had made coal-washers with vertical piston-rods about the year 1876.

The PRESIDENT said that in 1880 there were only four coal-washers in operation in Scotland. Mr. Rowan's paper was an interesting contribution to the history of the subject.

Mr. ARCHIBALD HOOD (Cardiff) wrote that Mr. Rowan stated that the first cylindrical screen for screening coal was proposed by Mr. Dutton in 1867. He might mention that he had a Walker circular screen working at the Bankhead colliery in 1853 or 1854. Another was erected at the Stonelaw colliery shortly afterwards.

* *Trans. Fed. Inst.*, vol. vii., page 587, and vol. viii., page 204.

‡ *Trans. Fed. Inst.*, vol. viii., page 210.

Mr. ROWAN stated that he had been unable to find the patent specification of Mr. Walker's screen prior to the year 1856, which is later than the date mentioned by Mr. Hood. Such a device may have been patented in some other name, but even under "subject-matter" classification, he could not find a record of it. Under the circumstances, he regretted that he could not say anything about the plan.

The discussion of the paper was then closed, after a vote of thanks had been accorded to the author.

DISCUSSION ON MR. ROSS' PAPER ON "THE ROSS ROCK-DRILL."*

Mr. ARCHIBALD (Cambuslang) said that when the members saw the Ross rock-drill at work some of them noticed (when it was boring in sandstone), that it became choked before the drill had bored 18 inches of hole. The spiral screw on the boring-bit was only about 5 inches long, and consequently too short, to give sufficient clearance, for the length of hole. If this small detail were rectified, the drill otherwise should do its work in a satisfactory manner.

Mr. FAULDS (Cambuslang) said that the drill when he saw it was working in sandstone and whinstone, and some of the members thought that it was a very good tool for caulking purposes, and perhaps for dressing stone. It did not seem to work so satisfactorily in hard as in soft stone.

Mr. ROSS, in reply, stated the drill should be withdrawn when it had penetrated to a depth of, say, 1 foot. At the same time, the drill could be withdrawn and the hole cleaned, and still do more work in less time than any other drill. The test referred to by Mr. Archibald and Mr. Faulds was made at the request of a gentleman who was desirous of seeing how far the drill would bore in a downward direction at an angle of about 40 degrees before it choked; and this trial had no bearing whatever as to the efficiency of the drill. The strain on the hand-wheel guides the operator exactly when to withdraw the drill and clean the hole, after which boring will proceed as before. The pressure on the automatic feed was possibly rather strong when boring downwards in the sandstone, although right for whinstone or granite. The results, he considered, were very satisfactory, viz., to bore a hole $1\frac{1}{4}$ inches in diameter in the hardest whinstone at the rate of from 4 to 6 inches per minute, and in soft sandstone at from 20 to 24 inches per minute.

* *Trans. Fed. Inst.*, vol. viii., page 205.

The PRESIDENT asked what was the air-pressure at the test?

Mr. Ross said that the compressed-air plant, available at their works, was put up for the purpose of testing caulking-tools, which were being made in large numbers. The rock-drill, while working on exactly the same principle, had a cylinder 2½ inches in diameter as against a diameter of 1½ inches in the caulking-tool, consequently it was impossible for the rock-drill to be supplied with a constant pressure of air at 60 pounds per square inch, the pressure best adapted to work it. The experimental drilling that had been seen by the members lasted only one minute at a time, and during that period the pressure fell from 60 to under 40 pounds, giving a mean pressure of much less than 50 pounds per square inch.

The PRESIDENT thought it was desirable that the drill should be tried at the coal-face, where compressed-air was available.

The PRESIDENT in closing the discussion, moved that a vote of thanks be accorded to Mr. Ross for his paper.

The vote of thanks was agreed to.

Mr. A. M. GRANT read the following "Remarks on Winding Engines":—

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the valve-chest cover. By this means the pressure was taken off the back of the valve, but the result was not satisfactory, as the engineman sometimes tightened the screws too much, and jammed the valve between the valve-chest cover and the valve-face, so that the valve could hardly be moved. Sometimes it was too slack, and steam got to the back of the valve and destroyed any equilibrium there was in it. The difficulty was remedied by re-arranging the reversing-handles and levers, but the engineman had a longer distance to go through with his handle when moving from forward to backward gear, and *vice-versa.*

The second engine was fitted with the same balanced slide-valve and the Allan link motion, as it was thought that the less space required by this motion from forward to backward gear would enable the reversing of the engine to be easily effected under a pressure of 80 lbs. per square inch. This arrangement was a slight improvement upon the first engine, but required less power to be put into the lever.

Fig. 2 (Plate XXII.) is another form of balanced slide-valve. It was fitted to an engine with two cylinders, each 26 inches in diameter by 5 feet stroke, for a working pressure of 100 lbs. per square inch. Another engine with two cylinders, each 30 inches in diameter and 5 feet stroke, is fitted with the same type of valve, but it is working at the lower pressure of about 50 lbs. per square inch. The application of the valves to the first engines was a failure, but the writer has not been able to determine the cause. There is no doubt, if the steam ports were made of less area, and as long as possible in proportion to their width, that the valve could be made very much lighter, and the travel on the valve and quadrant considerably reduced, giving the engineman more power at the reversing-handle. There was some difference of opinion among experts about this question. As the suggestions involved the expense of new cylinders and valves, a steam starting-engine was applied, and has given most satisfactory results.

Another form of balanced slide-valve has been fitted to another colliery winding engine. The suggestions as to decreasing the travel of the valve, and increasing the power at the engineman's hand with a reduced movement, have been to a very great extent carried out with very good results. Fig. 3 (Plate XXII.) shows this valve. It is not nearly so heavy as the other valves, and is a satisfactory form of an ordinary balanced slide-valve.

The Frew equilibrium or balanced slide-valve consists of two parts (Figs. 4, 5, and 6, Plate XXII.): a main valve *A*, with a balanced piston *B* fitted steam-tight into and carried with the main valve. The balanced

piston is arranged so as to work steam-tight against the valve-chest cover, and the face of the main valve *A* works steam-tight against the port-face of the cylinder *C*. The live steam from the boiler is admitted by what is usually the exhaust opening at *D* to the centre of the main valve at *A*, and passes thence to the ends of the cylinder through the ports *E*, *E*, for driving the engine, and by alternate action, actuated in the usual manner by eccentric rods and valve-spindle, the exhaust steam from the ends of the cylinder returns through the ports *E*, *E*, from the outer edge of the valve into the valve-chest *F*, *F*, which is really an exhaust-box, and escapes thence into the atmosphere. It will be seen from the foregoing description that there is little or no pressure in the valve-chest, that the stuffing-box of the valve-chest requires no packing and casing, and that the casing-cover requires little or no jointing. The balanced piston *B* is used to lock the steam in the valve, the recess is supplied with high-pressure steam from the inside of the main valve through small holes in the web or diaphragm *G*, and by having the cavity or recess next to the valve-chest cover a little smaller in area than that of the main valve, a nearly complete balance is effected by the opposing pressures of the steam. The main valve has a greater area exposed to the high-pressure steam of from 2 to 5 square inches (varying according to the size of valve) more than the area of each steam port, so as to ensure the valve working steam-tight against the cylinder valve-face. Two steel springs and lock-pads are placed in two pockets *H*, cast on the valve-lips, and, acting between the valve-lips and the balance-piston, maintain and keep in their places or respective faces (when the engine is running without steam), and return the valve to the face in the event of checking or priming. It may be noted that the action of the live steam tends to keep each part to the working-faces, and thus an automatic adjustment for wear is provided in a natural way, no set screws or other mechanical adjustments being required. The valve comes easily off the cylinder face in the event of undue compression in the cylinders, consequently no relief valves are required as in the case of Cornish and other piston valves. This valve has many good features, and will no doubt be more generally adopted when it is better known.

The writer was interested in the construction of the largest valve of the Frew type that has yet been made for a winding engine, viz., that on a coupled horizontal engine, with cylinders 24 inches in diameter and 5 feet stroke, working at 80 lbs. per square inch steam pressure. The first valve was not quite efficient, the balancing piston being made too

small, allowing of a slight escape of steam. A new valve was put in, properly proportioned. It worked, and has been working well for nearly a year.

The same type of valve has been adopted and is working very well on two winding engines with two horizontal cylinders, each 20 inches in diameter and 4 feet stroke, working at 80 lbs. per square inch of steam pressure; and also upon a horizontal engine driving a coal-washing plant. This engine has a very neat and effective automatic cut-off valve and gear, which is easily applied with this valve, and could be usefully applied on a fan or any constant-running engine. It has this also in its favour, that if it did not turn out satisfactorily, it could be easily altered into the present arrangement of steam admission.

With regard to piston-valves, the writer has seen them, but has not had any experience in their working on winding engines. He has applied them, however, to rolling-mill engines, etc., where for rapid reversing they are always worked by a steam starting-engine. The valve being made for the admission of steam between the valves, should be in perfect equilibrium and easily handled. The only objections that might be put forward against piston-valves are that they wear very rapidly, that there is no means of adjusting them to the face, and that leakage of steam would take place into the cylinders. Should the steam-stop valves be leaking, as they do frequently, and if the attendant should not be at hand, or not observe it, the engine might creep away and do some damage. This idea has occurred to the writer, but there may be no great practical value in it. However, it is worth consideration.

The valve and gear that the writer thinks is the best for large high-speed winding engines (cylinders above 26 inches in diameter), working at high pressure, is the Cornish double-beat or equilibrium valve. This valve scarcely requires description, as the type must be familiar to all. With it the engineman has little more to do under any circumstances than lift the weight of the valve in reversing, consequently the engine is easily handled under any pressure. An automatic cut-off gear can easily be applied, resulting in a saving in steam, rather than trusting solely to the handling of the engine by the attendant. The valves and seats should be strong and of the very best design and workmanship when working under high pressures, say of 100 lbs. and over, otherwise they will give trouble and never be steam-tight.

In some cases the steam and exhaust-valves have been made far too small, with the result that excessive back pressure is produced, and consequent waste of steam. These losses may be avoided if the valves

are made of sufficient size, and fitted with properly designed valve-gear, so that the valves may be lifted quickly and at the right moment.

It may be worth mentioning that engineers in South Africa are favouring the use of very high pressures (150 lbs. per square inch) and high-class Corliss valve-gear with trips or cut-off motion. This type of valve and gear is very economical, as the steam passages are short, and the gear can be arranged for an early cut-off, but it is costly and the mechanism is very fine. It must have been adopted for the purpose of economising fuel, which is somewhat expensive in South Africa.

A few words now on the arrangements of drums and brakes. It is most desirable that in all powerful high speed winding engines, a most efficient and reliable brake should be arranged. In this district the favourite brake was the upright clamp form, somewhat similar to that shown in Fig. 7 (Plate XXII.). This is not the best form of clamp-brake. The one shown in Fig. 8 (Plate XXII.) is much more efficient. In the first type, the leverage is so great, and the lever so long, with the power required, coming almost exactly between the fulcrum and the power applied, that the long lever springs and leaves its work. In the second arrangement, the power applied is as near as possible above the centre of the drum, no springing exists, and a proper arrangement of levers will stop any engine under full steam.

There is another form of brake which the writer has seen at work in North Staffordshire, on a large vertical winding engine. It is of the strap form, and is shown in Fig. 9 (Plate XXII.). It is arranged underneath the drum, thus avoiding any loss from friction, as it immediately loses all contact with the brake-ring, when released. The engine to which it was applied had cylinders 36 inches in diameter and 6 feet stroke, and a drum about 18 feet in diameter. The engineman could put on the brake with perfect ease either with hand or steam, and he had the engine under perfect control. The power is obtained from the toggle-joint arrangement, somewhat similar to the brake-connexions on large locomotives. It is a very powerful combination of levers, and the writer considers that this strap-brake was the best he had ever seen for the application of hand or steam power. It could be easily adapted to existing engines that are short of brake power.

Mr. Arnott said that he had been using a Cornish valve for over ten years, and had experienced no difficulty except when the packing was tight.

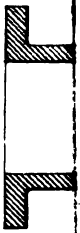
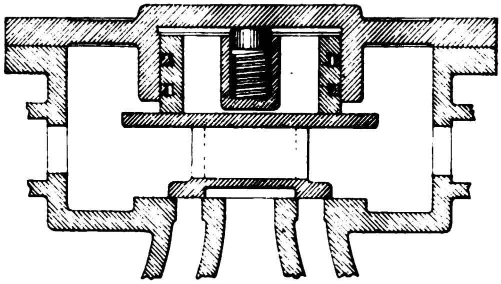
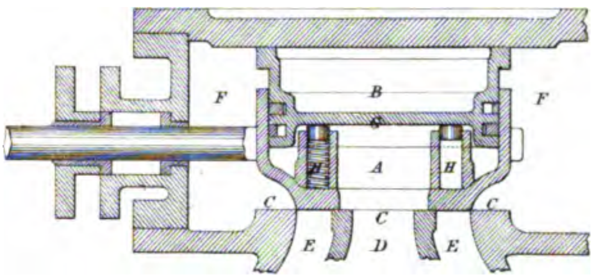


Fig. 3.



Scale 1 Foot to 1 Inch

Fig. 4.



Scale 1 Foot to 1 Inch

Fig. 9.

Scale 10 Feet to 1 Inch

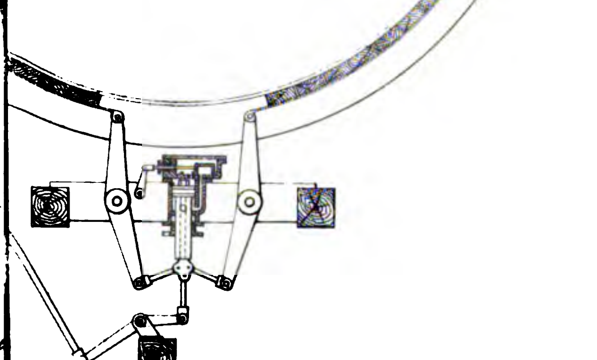


Fig. 6.

Mr. Frew enquired if it was not troublesome during the course of a winding?

Mr. Arnott.—No.

Mr. Walter Dixon said that Mr. Grant had mentioned some difficulty —he did not exactly say what—in regard to piston-valves. He had no experience of horizontal engines fitted with this class of slide-valve, but he had had experience of vertical engines in which piston-valves were used very successfully; and he thought that little or no difficulty would be experienced in applying them to horizontal winding engines, if they were not already used on such engines.

Mr. Grant said the difficulty he referred to was with regard to marine engines. If the piston-valve was leaking, it was likely to do so without the engineman knowing it. There was more liability for the piston-valve to leak than the piston, because the surface was not nearly so great.

Mr. Glen said that the pressure would not be accumulated in the cylinder although the steam escaped.

Mr. Grant said that they could at least get half a stroke, if nothing more.

The discussion was then adjourned.

Mr. J. G. Barclay read the following papers on "The Barclay Crown-valve Exhaust-gear," and on an "Overhanging Beam Pumping Engine.":—

THE BARCLAY CROWN-VALVE EXHAUST-GEAR.

BY JOHN G. BARCLAY.

The Barclay crown-valve exhaust-gear is an improved construction of the operating mechanism or gear for the exhaust and steam valves—crown or Cornish equilibrium—of winding and like engines. Heretofore there has been a considerable back pressure in the cylinders of these engines entailing a great waste or expenditure of steam, but by improved

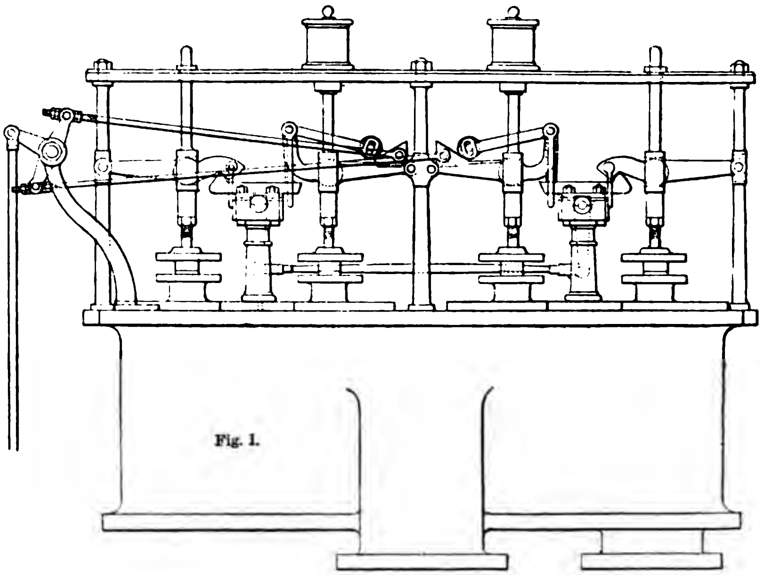


Fig. 1.

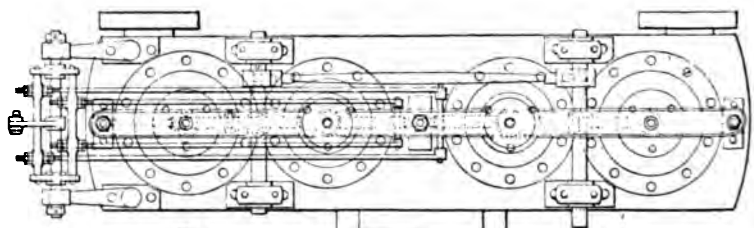


Fig. 2.

devices the exhaust-valve is opened quickly and kept full open to the end of the stroke, whereby this back pressure is obviated and the steam economized.

The oscillating levers which operate the exhaust-valves are formed each of a knee or recessed club shape on its acting surface, instead of being straight as heretofore. The oscillating or vibrating organ, actuated through link gear from the eccentric mechanism, which operates the lever mechanism of the exhaust and steam-valves, is also formed with a projecting or toothed face, its acting-surface being cut to the same angle as the kneed face of the exhaust-valve lever, so that it may, in its oscillatory movements, come into acting contact therewith and operate the lever to open or close the exhaust-valve. The oscillatory organ is formed with an extended segmental convex or cam surface beyond the aforesaid angled face, and the exhaust-valve lever is formed with a corresponding concave or curved face beyond the angled surface, acted on by the angled face of the organ, so that when the latter has oscillated or moved the lever beyond the angled faces, the convex curved surface of the moving organ will be in contact with the concave surface of the lever and so keep the exhaust-valve wide open, until, on the return oscillation of the organ, its angled face comes into contact with the corresponding face of the valve-lever.

The other arm or horn of the oscillating organ operates, by its to-and-fro motion, the oscillatory lever-mechanism of the steam-valve in the usual manner (Figs. 1 and 2).

OVERHANGING BEAM PUMPING ENGINE.

By JOHN G. BARCLAY.

The object of this design (Figs. 1, 2, and 3, Plate XXIII.) is to provide a convenient vertical underground pumping engine for deep or high lifts.

The pump is double acting, and can either be placed on the bed-plate of the engine, or 10 or 20 feet farther down the shaft, with a suction-pipe from the pump to the sump or lodgment. This allows the engine to be placed a few feet above the level of the water in the sump.

The weight of the 10 or 20 feet of rods is balanced by the diameter of the pump-rod through the stuffing-box being made of such a size as to equalize the weight of the beam, piston, and pump-rods—by allowing the pump to throw a smaller quantity of water in the upstroke than it does when on the downstroke, the pump-barrel being of the same uniform diameter throughout.

By this device the engine is perfectly balanced both ways, without any back balance-beam or weight on the fly-wheels being required.

The weight of the beam, pistons, and rods gives out the power in descending of the steam required to lift them, thus keeping the engine on the balance.

The engine is on the principle of the Barclay overhanging beam type, with high and low pressure cylinders and condenser.

Where it is safe to place these engines underground, a large amount of money may be saved by dispensing with the large engine aboveground and the heavy pump-rods and forcing pumps down the shaft.

The principal object of this engine is to get underground engines and pumps to work vertically. Everyone acquainted with underground horizontal pumps knows that there is a great amount of loss by leakage and friction, owing to the wear on the underside of the cylinders and pumps when working at a pressure equal to 1,200 feet head of water.

Mr. ARCHIBALD (Cambuslang) said that he had had considerable experience with the Barclay overhanging beam pumping engine, when the engine was placed on the surface, the pump-rods being from 12 to 18 inches square. The principle of the arrangement was that the weight of the pump-rods was greater than the weight of water in the vertical column of pumps. In Mr. Barclay's new design of placing this type of engine down the pit, the object is to dispense with the pump-rods. But against the saving of pump-rods, etc., there will be the expense of taking steam down the shaft in pipes, or, what is equally objectionable, of placing boilers underground to supply the engine with steam.

Mr. FAULDS (Cambuslang) asked Mr. Barclay if there were any of these pumps in use?

The discussion was then adjourned.

To illustrate Mr. J. G. Barclay's Paper on "Overhanging Beam Pumping Engine."

Side Elevation.

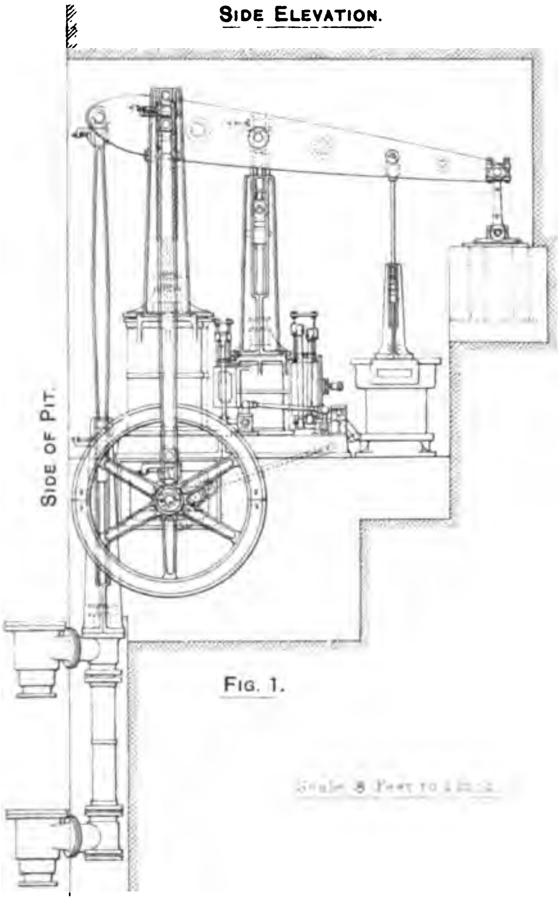


Fig. 1.

End Elevation.

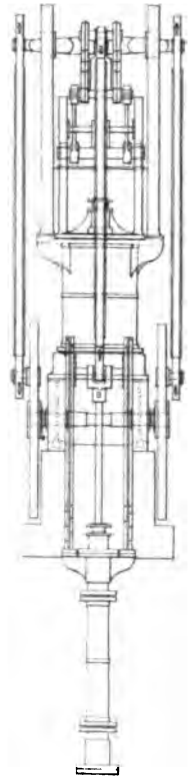


Fig. 3.

Ground Plan.

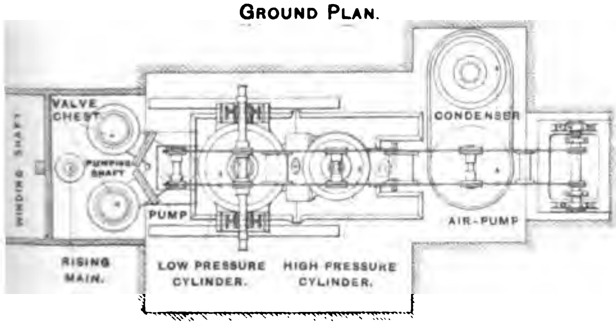


Fig. 2.

Andw Reid & Co. Ltd. Newcastle

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE MASON SCIENCE COLLEGE, BIRMINGHAM, FEBRUARY 12TH, 1895.

MR. W. N. ATKINSON, PRESIDENT, IN THE CHAIR.

AUDLEY COLLIERY DISASTER.

Mr. EMERSON BAINBRIDGE (Sheffield) moved that this meeting desired to express its deep sympathy with the sufferers by the disastrous accident at the Audley colliery.

Mr. T. FORSTER-BROWN (Cardiff) seconded the motion, which was agreed to.

PRIZES.

The SECRETARY announced that the Council had awarded prizes of books to the writers of the following papers, which had been published in volumes vi. and vii. of the *Transactions*:—

"A Contribution to our Knowledge of Coal-dust. Parts II. and III." By Dr. P. Phillips Bedson and Mr. W. McConnell, Jun.

"The Transmission of Power by Compressed Air." By Prof. Goodman.

"The Friction of, or Resistance to, Air-currents in Mines." By Mr. D. Murgue.

"Result of an Experimental Research into Choke-damp Poisoning, with Special Reference to Oxygen as a Restorative." By Dr. W. Ernest Thomson.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, OXFORD, 1894.

The report of the delegate was read as follows:—

MANSFIELD WOODHOUSE,
OCTOBER 3RD, 1894.

TO THE PRESIDENT AND COUNCIL OF THE FEDERATED INSTITUTION OF MINING ENGINEERS.

GENTLEMEN,—I attended the two conferences of delegates of the corresponding societies at the British Association meeting in Oxford in August last.

The only points discussed of interest to the Institution were:—

(*a*) What can be done to make local museums more popular? It was suggested that application should be made to the County Councils for aid in having short lectures and explanations of various objects in the museums. But it appeared to me that the best way was for the local natural history societies to do more in properly cataloguing the exhibits and arranging for some member to attend one afternoon each week to explain anything new or of interest to those visiting the museums.

(*b*) Earth-tremors. Mr. Darwin and others attended and explained what had been done lately in perfecting an instrument to record any movements in the earth's crust. It appeared that Mr. Darwin had now been successful, and would be glad to explain the instrument to any society or individual who would undertake to record observations. The instrument was fully explained in *Nature*,* and could be procured for about £60. This appeared to me a valuable instrument for such an institution as ours to possess, as the observations would be of great interest in a mining locality. The instrument does not show any sharp vibration that might be caused by a number of shots being fired at one time in a mine, so the observations could be made in a working colliery. I fear, however, that the expense of such observations will preclude our doing much at present.

(*c*) A report was read by Mr. De Rance before Section C on "The Circulation of Underground Waters," and I feel that these are observations which might be made by members of our Institution with great advantage, and I shall be glad if something can be done.

Beyond the points, which were discussed at the delegates' meeting, the following papers of interest were read before the various sections, viz.:—Prof. Unwin on "Methods of Determining the Dryness of Steam," Dr. Haldane on "The Causes and Prevention of Suffocation in Mines," and Dr. Shaw-Little on "Observations on the Effects of After-damp."

I do not propose to give a *résumé* of these papers as they can be obtained in the *Annual Report* of the British Association.—I am, yours faithfully,

M. H. MILLS.

A paper by Mr. F. G. Meachem upon "The Search for Coal beyond the Eastern Boundary-fault of the South Staffordshire Coal-field," etc., was then read:—

* July 12th, 1894.

THE SEARCH FOR COAL OVER THE EASTERN BOUNDARY-FAULT OF THE SOUTH STAFFORDSHIRE COAL-FIELD, WITH ESPECIAL REFERENCE TO THE SINKING AT HAMSTEAD COLLIERY AND THE WORKING OF THE THICK COAL-SEAM.

By F. G. MEACHEM.

INTRODUCTION.

Fifty years ago the eastern limits of the known South Staffordshire coal-field, with its celebrated ten yards coal-seam, was as shown on the map of the Geological Survey.* For many years this limit was accepted by mining engineers, but those who had given especial attention to the subject were of opinion that coal would be found over the then eastern boundary-fault.

The first of any trial borings on the east side of the great boundary-fault was made by Mr. James Horton, at Smethwick, and the failure is fully described in *The Miners' Guide*, by Mr. Thomas Smith, who gives it as an instance in support of the following statement:—

> Such a view of the subject would seem to indicate that the limits we have mentioned, as enclosing the richer coal-field of South Staffordshire, were originally marked by nature as its boundaries; and that the ten-yards coal dismembered and lost near Bilston, and divided into several seams towards Stourbridge, will not in any direction be found to extend far beyond its present known limits.†

About this time, Sir Roderick Murchison was surveying in the Staffordshire district, and in his *Silurian System* and other writings, he expressed the opinion that coal would be found east of the then well-known fault. The Earl of Dartmouth made a trial at the Heath pits. This trial was successful; it added to the coal-field a strip ¾ mile wide, and gave a healthy stimulus to farther explorations.

In 1865, Mr. H. Johnson, of Dudley, read a paper before the British Association for the Advancement of Science, in which he dealt with the extension of the South Staffordshire coal-field. Sir R. Murchison stated that he had no doubt that coal would be found farther eastward, and that it would be of superior quality to that of the then known coal-field,

* *Trans. Fed. Inst.*, vol. iii., plate I., page 48. † Page 20.

because that coal was broken by the extension of Silurian and igneous rocks. As that coal-field is tending towards exhaustion, it is cheering to know that extensive beds of coal will be worked in future ages under some of the red rocks of the Midland counties.

In 1850, however, Prof. Jukes, whilst working in this district, had an opportunity of inspecting the fault then supposed to form the boundary of the coal-field, and in his paper "On the Geology of the South Staffordshire Coal-field,"* he says :—

> The most curious fact, however, is that there is a sudden rise of the Silurian rocks both at the Heath and Lewisham pits, through the Coal-measures; and this I am inclined to believe is not in consequence of any fault, but is due to their having formed an old Silurian bank of high ground during the Coal-measure period, and that the Coal-measures were deposited against that bank, its existence being favourable to the formation of sandstone and the accumulation of clay, but unfavourable to the formation of coal. The extension of this "rock fault" and old Silurian bank is at present uncertain; it appears, however, either that they extend continuously for 3 miles to the south of West Bromwich. . . .

He also expressed the opinion that it would be unwise to sink for coal eastward of the boundary-fault. Trial-sinkings were made, however, to the east of this fault, notably one at Friar Park, near Wednesbury in 1849.† Lord Dartmouth, about 1850, put down two boreholes in Sandwell Park; they were not successful. A pit was also sunk near Wigmore; thin coals and ironstones were found, and the Silurian shales were struck, showing that the floor of the coal-field was reached. Other trials were made to the south of the boundary, but without success.

Notwithstanding these failures, the late Mr. H. Johnson's opinion that a new coal-field lay under the red rocks continued to gain ground, and in 1870 a prospectus proposing a trial-sinking for coal to be made near West Bromwich was issued, with the result that the well-known Sandwell Park colliery was sunk. This successful venture led to the formation of the Hamstead Colliery Company, whose estate, as originally purchased, comprised 500 acres of surface and mines, and the various additions since made have increased the total area to 1,100 acres of freehold and leasehold estates.

GEOLOGY.

The Hamstead colliery is situated in the valley of the river Tame, which flows through an undulating sandstone country until it joins the river Trent. This valley is, no doubt, in part, at least the result of ice-action, for in a well recently sunk near the colliery, at a depth of 48 feet

* *Records of the School of Mines*, vol. i., page 257. † *Ibid.*, page 271.

a bed of boulder clay was reached, underlying a very thick bed of clay void of pebbles. The boulders were all local rocks, which are yielded by the neighbouring coal-field. Without exception they are striated, and were, no doubt, dropped at the end of a glacier when the summer heat caused its retreat towards the hills.

The surface-beds at Hamstead consist of red sandstones and marls, reaching to a depth of 627 feet, without a trace of fossils. Occasionally sun-cracks, worm-burrows, and ripple-marks of large size are found on slabs of sandstone lying a few feet below the surface. The writer cannot see any lithological difference between this the first set of rocks and those lying below a depth of 627 feet, and the rocks seem to him to be transition-beds between true Coal-measures and the overlying Trias, partaking of the characters of both.

The Hamstead shafts passed through the whole assemblage of transition-beds and true Coal-measures, the strata are found dipping at various angles; but, though varying in amount, the direction of the dip is constant towards the south-east. This circumstance may be explained by considering that the lower strata, inclining at a greater angle than the succeeding beds, formed an old land-surface, consolidated and upheaved before the upper beds were laid down, and that subsequent upheavals have produced the varying dips.

If a bed of sandstone, dipping at an angle of, say, 15 degrees to the south-east, formed a land-surface upon which sandstone was again deposited, there would then be a horizontal bed lying upon an inclined one; should those rocks be thrown down to a farther dip of say 15 degrees to the south-east, then the upper beds would dip at an angle of 15 degrees, and the lower beds would dip at an angle of 30 degrees, 15 degrees being added to their former dip of 15 degrees.

At a depth of 1,350 feet a remarkable unconformity of the strata was found. Above a bed of white sandstone was found a bed of conglomerate, whose very irregular upper surfaces were filled by the lower portions of a thick bed of variegated sandstone. This occurrence was an undoubted proof that a long period of time elapsed between the formation of the bed of conglomerate and the overlying variegated sandstone, that the conglomerate-bed had suffered erosion as a land-surface, and that it had been again submerged and buried beneath the silt of an extensive lake.

Sinking operations were commenced in 1875, and the most careful record of every stratum passed through was kept, together with rock-specimens. When fossils were found particular care was taken in describing and forming lists of them. The need of a guide through the

red rocks, covering the Coal-measures at such a depth, was keenly felt by the writer, and he determined to make a complete record of his own work as a guide to future explorers. He also kept an exact record of the amount of water-yield at the various depths.

The specimens of the fossil flora were all labelled and submitted to Mr. Kidston, F.G.S., of Stirling, who kindly confirmed the writer's list, and made all necessary additions. The Mollusca were named and classified by Mr. John Young, F.G.S., who considered them to be of very considerable interest and importance.

The following tabular section records the fossils found in the Hamstead shafts :—

Depth from Surface. Feet.	Thickness of Strata. Feet.	Description of Strata.	Fossil Contents.
Surface to 627 ...	— ...	Red and brown sandstones and light red marls	
627 ...	6 ...	Light marl	(?) Rachis of fern.
729 ...	102 ...	Red marl	Odontopteris Lindleyana, Sternb.
802 ...	— ...	Unconformity	
1,008 to 1,038 ...	30 ...	Red marl (13½ feet) and red sandstone with raindrop impressions, and sun-cracks occurring at a depth of 1,008 feet, in a blue band 6 inches thick. The *Spirorbis* Limestone occurs at a depth of 1,024 feet, with a thickness of 8 inches	Pecopteris arborescens Schl., sp. " unita, Brongt. " Miltoni, Artis, sp. Neuropteris ovata, Hoffm. " Scheuchzeri, Hoffm. " flexuosa, Sternb. Alethopteris aquilina, Schl., sp. Calamites, sp. Annularia stellata, Schl., sp. Sphenophyllum emarginatum, Brong. Lepidophyllum lanceolatum, L. & H. Cyperites bicarinata, L. & H. Cordaites angulosostriatus, Grand' Eury.
1,050 ...	39 ...	Brick-coloured marls	Walchia imbricata, Schimper.
1,200 ...	16½...	Light purple rocky marl ...	Neuropteris rarinervis (Bunbury).
1,233 ...	9 ...	Purple and red shale	Calamites, sp. Pecopteris Miltoni, Artis, sp. " sp. Neuropteris rarinervis (Bunbury). Annularia stellata, Schl. Cyperitis bicarinata, L. & H. Lepidostrobus, sp. Stigmaria ficoides, Sternb., sp. Walchia imbricata, Schimper.

Depth from Surface. Feet.	Thickness of Strata. Feet.	Description of Strata.	Fossil Contents.
1,320 ..	72 ...	Red sandstones and grey shales	Calamites Suckowii, Brongt. „ undulatus, Sternb. „ varians, Sternb. (var.). Alethopteris decurrens, Artis, sp. Lepidodendron Wortheni, Lesqx. Lepidostrobus variabilis, L. & H. Sigillaria, sp. Pinnularia capellacea, L. & H. Sternbergia approximata, Brongt.
1,353 ...	— ...	Unconformity and erosion of strata. Measures below this depth assume a purpler hue	
1,599 to 1,608 ...	9 ...	Blue bind	Calamites varians, Sternb. (var.). Calamocladus equisetiformis. Lepidodendron aculeatum, Sternb. Lepidostrobus variabilis, L. & H. Sigillaria reniformis, Bgt. „ mamillaris, Bgt. „ sp. Cyperites bicarinata, L. & H. Stigmaria ficoides, Sternb., sp. Cordaites, sp. Cardiocarpus Meachemii, Kidst., sp.
1,650 ...	3 ...	Grey shale	Carpolithus ovoideus, Gopp & Berger. Eamondia rudis, M'Coy.
1,655 ...	4 ...	Dark grey clod...	Productus semireticulatus, Martin. „ scabriculus, Martin. Edmondia rudis, M'Coy. Modiola lingualis, Phill. Anthrocosia Urei, Flem (= acuta) Sow. Leda attenuata, Flem. Goniatites, sp., allied to G. excavatus, Phill. Schizodus allied to S. carbonarius, Portl.
1,752 ...	9 ...	Purple and grey shales ...	Calamites Suckowii, Brongt. Neuropteris rarinervis (Bunbury). Mariopteris muricata, Schl., var. Nervosa (Brongt., sp.).
1,845 ...	— ...	Top of thick coal-seam, the shales above it are devoid of fossils	
1,869 ...	6 ...	Shales with ironstones ...	A few fossils, chiefly Stigmaria.
1,893 ...	— ...	Heathen coal-seam	

At the meeting of the British Association for the Advancement of Science, held at Birmingham in 1886, the writer and Mr. H. Insley read

some "Notes on the Rocks between the Thick Coal-seam and the Trias, north of Birmingham, and the old South Staffordshire Coal-field."* This paper contains the only published opinion that the red shales below the Trias of this district belong to the true Coal-measures.

On a comparison of the fossils found in the red shales, they are found to be identical with those found in the deep-seated black shales which accompany the coal-seams. This fact proved that there was no break in the continuity of the series, and the presence of true Carboniferous fossils to a depth of 627 feet below the surface certainly placed all the rocks in the category of Coal-measures, and although a most careful search was made for any Permian fossils none have ever been found.

The *Spirorbis* limestone is a somewhat earthy limestone (grey in colour, but sometimes inclining to pink), which is characterized by the presence of fossil Serpulæ (*Spirorbis carbonarius*). It is strange that these are the only organic remains found in this rock; life must have been confined to lowly organized types during its deposition. Whether it was a marine deposit laid down in the open sea is a moot point; the writer is inclined to the idea that its formation took place in widespread, shallow waters, to which the sea may have had access at high tides. It is constant in its position as a member of the Coal-measures, affording thereby a reliable horizon to the explorer for coal. When the *Spirorbis* limestone is found in boring, it is certain that true Coal-measures are present, and that the thick coal-seam or its equivalents may be found. This bed attains considerable thickness in the Lancashire and North Staffordshire coal-fields, becoming thinner in Shropshire, and extends into South Staffordshire. At Sandwell Park colliery, it is 10 inches thick, lying at a depth of 369 feet from the surface and 885 feet above the thick coal-seam. At Hamstead colliery it is 12 inches thick, at 1,023 feet below the surface and 831 feet above the thick coal-seam. The same bed is found in the Forest of Wyre and Warwickshire coal-fields.

The Espley rock, from its name, gives no indication whatever of its nature, or clue to its parentage. It is found in the Hamstead shaft at various depths, the thickest bed (2 feet) being found at a depth of 1,683 feet. On close examination it appears to be an old volcanic ash, somewhat felsitic. It is very hard and compact, and resists the action of weather on the spoil-bank. These beds of ash thicken in a south-westerly direction, showing that the volcanoes from which they were derived were there located. At the time of their deposition, the area now covered by

* *Report*, 1886, page 626.

the ash-beds was probably a large lagoon or bay of the sea, and the ashes were ejected from the craters, just as they are to-day from Vesuvius and other volcanoes. The ash falling on the water would sink and form a compact cement-like band. The activity of the volcanoes gradually declined, and this ash-like material is found intermingled with the sandstones in thin beds and patches. The volcanic activity must have ceased before the Triassic period, as no similar ash-deposits are found in that formation. Future investigations may perhaps localize exactly the source from which these most interesting beds have been derived.

Mode of Working the Thick Coal-seam.

The fact that the thick coal-seam is divided into seams with partings helps the process of working it. If the seam had formed one solid bed, it would have been an exceedingly difficult one to work. The thickness of the seam, and the liability to spontaneous combustion, renders it imperative at Hamstead colliery that the roads should be driven to the boundary, and the working of the coal then commenced. By this means the various sides of work are kept separate, and the fires are kept under control. If the working-faces were made longer the occurrence of a fire in one place would stop all the others, a large quantity of coal would be lost, and the output of the colliery reduced. By keeping the sides of work small and ventilating each of them separately, the loss of coal by fires is reduced, and a higher produce of coal per acre is maintained. The roof is also under better control, and the rock does not come down so far into the workings, or press so heavily on the working-faces of the coal.

The details of opening the panels off the main-roads are shown in Figs. 1 and 2 (Plate XXIV.). Two roads are driven and thirled at the back A, then the bottom coal C is undergone and taken out (Fig. 2) for a width of 30 feet, 6 feet timber being put up. The pikemen then proceed to cut the roof coal, C. When this coal is cut round, it lies on the timber and ties or spurns connecting the cut-coal to the sides of the place. The timber is then removed, or the spurns shot out or cut away with the pricker until the whole mass of coal is brought down. This is one of the most dangerous operations of mining in the thick coal-seam, and only well qualified workmen are allowed to undertake it. The writer has seen many thin-seam workmen look at it, and that sight has been enough for them. During the recent strike in the Cannock Chase, many workmen from the Chase applied for work at Hamstead colliery, but not one, unless he had worked before in the thick coal-seam, would go into the stalls.

If the entire height of the coal-seam does not come down in the first operation the process of timbering up to the remaining coal and cutting round is repeated until the rock-roof is reached.

At some collieries where the roof is strong all the bottom coal may be taken out, and the portions of the upper coal-seams intended for pillars are supported on wooden cogs. This is a valuable method, it is safer for the workmen, more coal is produced, and there is less liability to spontaneous combustion, but where the coal is lively and bumps are frequent, it is more dangerous, as the coal cuts on the sides of the pillars, and comes down before it is wanted.

Every coal-seam has its own peculiarity, and the best mode of working must be decided for each mine. This statement is especially true of the thick coal-seam. There is much to learn as to thick coal-mining at great depths.*

SPONTANEOUS COMBUSTION.

Prior to the year 1620, Dud Dudley wrote in his *Metallum Martis* that :—

> The lesser or small cole, which will bring no money, . . . heat naturally, and kindles in the middle of those great heaps; often fals the cole-works on fire, and flaming out of the pits, and continue burning like Ætna in Cicily, or Hecla in the Indies. Yet when these loose sulphurious compost of cole and sleck, being consumed in processe of time, the fire decayes, yet notwithstanding the fire hath continued in some pits many years, yet colliers have gotten coles again in those same pits, the fire not penitrating the solid and firme wall of coles, because, pabulum ignis est aer, the ayre could not penetrate.

The above is as good a description of spontaneous combustion as if it had been written to-day, and although much has been written on the question, we know but little more than was known two hundred and seventy-five years ago. It is still a fact that if fine slack be left in an opening it very soon fires, doubtless from the absorption of oxygen by the finely divided coal. It is the care of every good stallman, fireman, etc., employed about a thick coal-seam opening to have every particle of slack cleaned up, even if it has to be thrown away afterwards.

Another cause of these fires, and the most difficult to fight against, is fire in the breaks of the ribs and pillars of coal. The writer has been able several times to cross an opening to a fire, and found that it had originated in the breaks in the ribs, and the fire has been filled up

* Further details as to working the thick coal-seam will be found in *The Miners' Guide*, by Mr. Thomas Smith; *Report to the East Indian Railway Company*, 1887, Mr. Walter Saise; "The Thick Coal of South Staffordshire," Mr. H. W. Hughes, *British Society of Mining Students*, vol. ix., page 4; and "A General Description of the South Staffordshire Coal-field," etc., *Trans. Fed. Inst.*, vol. iii., page 25.

and a side of work has been saved from being lost. This led to the custom at the Hamstead colliery of not driving to the outside of the side-of-work with the preliminary roads (Fig. 1). It was found that the breaks always formed about 10 or 15 feet from the side of the road, and, in these breaks, the pressure and grinding of the coal always produced a fire, consequently by driving the road about 10 or 15 feet from where the rib was intended to be left, all loose coal could be cleaned out and cut away to the solid rib by the workman. This practice has been found of the greatest benefit, and has made the occurrence of fires much less frequent in the stalls. Possibly also, if the old opening could be crossed, and the ribs and pillars reached, other fires that are now dammed off might be filled up. The breaking down of the rock-roof prevents this from being done to any great extent, the openings being usually filled with hundreds of tons of rock as soon as they are finished.

At the Hamstead colliery, there is a new and probably more troublesome class of fires, owing to the greater depth, and that is: fires in the solid portions of the coal-seam, occurring especially in bolt-holes and main-roads.

Whenever a head or road is driven at right angles to one of the main-roads, or whenever a dam is inserted, it is found that the coal is fractured for a distance of 10 to 15 feet, and in a few cases the coal has been found completely broken up for a distance of 50 feet on one side of the road, although no openings have been worked nearer than 1,000 feet. The continual earth-movement grinds up the coal to fine flour in these breaks, which are continually taking fire. When fire breaks out the only thing to be done is to drive a head into the side, find the break, and go along it until the fire is reached.

Fig. 3 (Plate XXIV.) shows the site of a fire which occurred recently. Fire-stink was detected, the head A was driven, and another head was driven along the break B. The coal at C kept getting hotter, until the workmen could scarcely work in it; and at 8 feet from the side of the road the main break was found full of red-hot fire. As soon as the head B thirled into A, the air got access to the fire, which rapidly increased, and the flames came out at B, and had not the greatest care been exercised the timber would have taken fire. Water was immediately applied at A, and the steam generated soon extinguished the flames. The head from A to B was enlarged, the red-hot coal filled out, and the place then cooled down. Such occurrences are not unusual at this colliery. The only thing to be done is to at once cut off the air-current, go boldly into the seat of the fire with a head and load it out.

Whenever old geological breaks filled with calcite are met in the workings they give way (the calcite forming a hard rubbing-surface), and they take fire more quickly than any other breaks. If one of these calcite or white veins is found, where it is necessary to drive a bolt-hole, they are always avoided, and the bolt-hole is driven at a distance from it, as troubles will ensue if this portion of the seam be disturbed.

Effects of Pressure of Overlying Strata.

The effects of the weight of the 1,860 feet of rocks lying above the thick coal-seam soon became evident when the first gate-roads were driven, in the form of bumps (or earthquakes). About 450 feet from the pit-bottom, the first serious bump occurred. The road was entirely ruined and thrown in for a length of about 150 feet, and three men were injured. These bumps occur periodically and are most violent in new roads.*

Prof. Hull, speaking of the effects of pressure, says "In all probability one effect would be to increase the density of the coal itself."† This statement is contrary to experience observed at the Hamstead colliery, as the only observed effect of pressure is that of producing joints and fractures. It would appear that the coal had attained the maximum of solidity, and that farther pressure only forced it apart along lines of weak or imperfect cohesion.

Prof. Hull farther states that at Dukinfield colliery "where the black mine is now being worked at a depth of about 2,500 feet, the pressure is so resistless as to crush in circular arches of brick 4 feet in thickness." This crushing has also been experienced at Hamstead colliery, brickwork being useless and unable to withstand the great weight thrust upon it. One arch is 40 inches (nine courses of brick) in thickness, lined with sand, but it frequently gives way, and is a source of expense and anxiety. The great pressure has materially decreased the yield per acre and increased the proportion of slack-coal, and the cost of production (especially for timber and repairs).

In all future mining operations at great depths, this factor of weight will have to be seriously considered before new ventures are made, for, without doubt, a limit will be reached at which the cost of maintenance of roads and other underground works will become so great that the prices of coal will have to be materially advanced before the cost of production is covered and a margin of profit left.

* "Notes on an Earth Explosion, or 'Bump,' at Hamstead Colliery." By the Author, *Trans. Fed. Inst.*, vol. v., page 381.

† *Coal-fields of Great Britain.* Third Edition, page 447.

Gate-roads.

The gate-roads are driven about 9 feet in width at the bottom and 6 feet high (7 feet coal-trees and 6 feet bars being used, and owing to the heavy weight and liability to bump this timber has an average girth of 7 to 9 inches). Nearly every kind of timber has been tried, but for endurance and safety, larch is found to be the most suitable. Steel bars have also been used with satisfactory results. The roads are mostly driven in pairs, about 100 feet apart, suitable for work at the face, and allowing of the formation of 30 feet openings and 30 feet pillars.

As a rule the best position for the roads—both for standing after being driven and during driving—is the middle of the seam, leaving the sawyer and benches coals under foot. And as the roads creep or blow up, it then leaves coal-bating. The best position for the roads in the coal has been a matter of great discussion, but experience has shown that at Hamstead colliery the middle of the seam is the best. Where places have been driven in the lower coal for the purposes of making air-crossings or landing-places, bottom-fires have frequently occurred, and there has been an extra amount of dirt-bating. After the benches coal is taken up, the fire-clay underneath the coal-seam heaves and blows up. When places are driven in the upper portion of the coal-seam, the rock-roof invariably comes down, and the coal breaks for a considerable distance along the sides of the roadways.

Main haulage-roads are driven 10 feet wide at the top, 12 feet wide at the bottom, and 6 feet high.

The creep or blowing up of the roads in deep mines is a most serious item. The writer has made several tests, and it is no unusual thing to get 7 inches of blowing up in from 24 to 36 hours, hence the amount of dirt to be drawn from the mine is greatly increased.

Temperature of the Mine and of the Strata.

The increase of temperature of the earth's strata occupied some little attention during the sinking of the Hamstead shafts, but the general results obtained did not in any way accord with the accepted theory that the temperature of the earth's crust increased 1 deg. Fahr. for every 60 feet of increase of depth after the first 30 feet. The readings of the thermometers in the shafts agreed with those obtained at the Rose Bridge and other sinking shafts. The writer thinks that these results were not the temperature of the strata, but the temperature of the working-place, and that the greater part of the increase of heat was due to the workmen, blasting, etc. This opinion was confirmed when the

thermometer was put into a hole full of water, as it invariably read much lower than when placed in a dry hole. In 1892, the writer was desirous of improving the ventilation and of cooling, if possible, the working-places, wherefore he made a further series of observations, which are shown in the following table:—

	January 4th, 1892. 6 a.m. Barometer. Inches.	6 a.m. Thermometer. Degrees	6 p.m. Barometer. Inches.	6 p.m. Thermometer. Degrees.
Top of shaft	29·98	23	30·80	32
Bottom of shaft	32·15	49½	32·15	50
In the workings, 4,200 feet from pit-bottom ...	- -	76	—	76

These observations show an increase in the air-temperature from the surface to the workings of 53 degs. in the morning, while the increase in temperature at the surface during the day did not affect the temperature of the air in the mine.

An interesting experiment was also made to ascertain the exact temperature of the strata as compared with that of the ventilating-current. For this purpose, a place 4,000 feet from the shaft (and some 2,000 feet distant from all workings) was selected, where two roads were being driven. A hole was bored 10 feet into the solid coal on the side of the road. The temperature of the air at this place was 76 degs. A maximum and minimum thermometer was then placed in the back of the hole, which was sealed up with clay and allowed to remain for 1¼ hours; and when drawn out the minimum thermometer indicated 66 degs. This observation did not accord with the writer's rule and the experience of Rose Bridge and Dunkinfield collieries, otherwise the reading would have been at least 75 to 87 degs. Farther temperature observations were then made, as shown in the following table:—

Date.	Surface in Shade.	Bottom of Downcast Shaft.	Workings.	Return Air at Bottom of Upcast Shaft.	Surface in 1½ Feet of Soil.	In Borehole in Coal-seam.
	Degs.	Degs.	Degs.	Degs.	Degs.	Degs.
1894.						
January ...	23	49	76	—	Frozen	66
July ...	59	—	80	71	—	66
August ..	67	62	79	77½	59	66

These observations clearly prove that the temperature of the strata at a depth of 2,100 feet, was 66 degs. The temperature of the strata should have been (mean temperature at Hamstead colliery 49 degs., add 1 deg. for every 60 feet of depth or 33½ degs.), 82½ degs. Consequently, instead of the increase of temperature being 1 deg. for every 60 feet of depth, it is only 1 deg. in every 117½ feet of depth (thus an actual

temperature of 66 degs., less the mean temperature of 49, gives a difference of 17 degs., which, divided into 2,000 feet, gives 1 deg. for every 117½ feet of depth).

To this constant temperature of 66 degs. in the strata, must be added the heat produced by the lamps, candles, horses, workmen, and that generated by friction and by the grinding and heating of the coal in the innumerable breaks in the coal where the fires generate along the sides of the roads and in the workings. The above observations have been frequently repeated, and the writer did not find any difference in the temperature of the strata.

Prof. Hull states :—"From the above table it will be observed that at a depth of 3,000 feet the temperature of the strata exceeds that of blood-heat, and that were it not for the effects of ventilation in reducing the temperature, the limits of coal-mining would be circumscribed within this depth."* The experience at Hamstead colliery is that the temperature of the rocks is 66 degs. at a depth of 2,100 feet, while that of the air-current is 80 degs. The writer thinks that mining would be practicable even if the temperature of the rocks rose to 80 degs., and that the rate of increase in temperature, the farther the sinking continued, would not be that in general acceptance, and that even the increase shown by the Hamstead colliery experiments would not be maintained, but would probably be found something like a depth of 150 feet for every degree of increase in temperature. The writer cannot lose sight of the fact that all his experiments point to the above conclusion, but before the matter can be satisfactorily proved, the economical limits of the coal-mining would be reached.

Plant.

The No. 1 winding pit is 15 feet in diameter, with brick-coffering to a depth of 300 feet. The No. 2 pit (upcast and water pit) is 12 feet in diameter.

The No. 1 winding-engine has two cylinders, 44 inches in diameter and 7 feet stroke. The drum is 22 feet in diameter. The engine is fitted with a separate condenser, consisting of an engine with a cylinder 36 inches in diameter and 4 feet stroke, driving two air-pumps each 28 inches in diameter. The average vacuum produced is 10 lbs. The steam pressure is 45 lbs., and by aid of this separate condenser the output has been increased from 1,000 to 1,200 tons per day of eight hours. Valves are fitted so that the engine may be worked with high pressure steam when desired. The cages have three decks, carry six tubs, and are run and changed in 70 seconds.

* *Coal-fields of Great Britain*, Third Edition, page 438.

The pit-frame is built of wrought-iron lattice girders. The height is 72 feet to the bearings of the pulleys, which are 18 feet in diameter.

The No. 2 winding-engine has 2 cylinders, each 33 inches in diameter and 5 feet stroke. The drum is 14 feet in diameter. Single-decked cages are used.

There are twenty-two boilers of the plain cylindrical and Lancashire types.

The haulage is all on the endless-rope system, with the rope running under the tubs. The engines are placed on the surface and the power conveyed down the shaft by means of ropes.

The colliery is ventilated by a Guibal fan 36 feet in diameter and 12 feet wide, driven by an engine with a cylinder 24 inches in diameter and 24 inches stroke. This fan at fifty-two revolutions per minute exhausts 100,000 cubic feet of air per minute, at 2½ inches of water-gauge.

The arch at the pit-bottom is 23 feet in diameter, built of nine courses of brickwork, with 1 foot of sand-backing and a course of oaken keys.

The canal-basin is reached by an incline, worked by an endless rope, and has accommodation for loading eight boats at one time and storage for about thirty loaded ones. Coal is conveyed to the land-sale depôt by an endless-rope haulage.

Mr. Sopwith (Cannock Chase) said that he had hoped that Mr. Meachem's paper would have given information as to the possible eastward extension of the South Staffordshire coal-field. The fact that the thick coal-seam had been found at Hamstead and Sandwell Park collieries did not necessarily prove that there would be an unbroken coal-field between South Staffordshire and Western Warwickshire. The fault, which at one time was considered to be the eastern boundary-fault, had been proved by the workings of the Walsall Wood and Aldridge collieries to be the first of two or more large faults dipping eastward. These collieries were working an area of coal between two faults, and beyond the fault that was originally considered to be the eastern boundary-fault. It was clearly established that farther east there was another very large fault, the throw of which has not been determined, but at a point 8 or 10 miles north from Hamstead colliery it seemed perfectly clear that an exploring drift had been driven through the very apex of the triangle formed by these two faults running together. The geological section

shown in going through this fault was a very curious one.* The lower series of coal-seams of the Cannock Chase coal-field, the well-known deep and shallow seams, were found just through the fault. The whole of the Coal-measures appeared to be passed through in the drift, that is to say from the lower to the upper coal-seams, but the greater number of these coal-seams are all jumbled together. The Coal-measures, whose normal section is something like 1,000 feet, are found in this drift to be compressed into a horizontal length of about 200 feet, owing to intervening measures having been squeezed out. Curiously enough, in trying to find out what was the extent of throw, independently of the investigations of Prof. Jukes, he had made out that at the very least the amount of the throw of the faults at this point was about 3,000 feet. It appeared to him to be perfectly clear that that was the least amount of throw which took place immediately east of the Cannock Chase coal-field. It would be very interesting to know how far the second fault affected the coal-field, running, as it did, in a south-easterly direction. Whether the fault went as far south as the latitude of Hamstead colliery he could not say. He was somewhat disappointed to find that Mr. Meachem had made no suggestions as to the eastward extension of the thick coal-seam. Unless there was an unknown Silurian bank east of the Cannock Chase part of the coal-field, there would be an enormous area of the separated part of the thick coal-seam found east of the known coal-field.

Mr. DANIEL JONES noticed the following passage in Mr. Meachem's paper:—"When the *Spirorbis* limestone is found in boring, it is certain that true Coal-measures are present, and that the thick coal-seam or its equivalents may be found." He was afraid this remark might lead to erroneous conclusions. The statement was, no doubt, applicable to Hamstead colliery and to the particular localities where the thick coal-seam did exist. He must caution the members that the statement was not applicable to the *Spirorbis* limestone as it occurred in other parts of the country. In the Forest of Wyre coal-field, the *Spirorbis* limestone, which occurred over a very large area, was found in some portions of the district within a very short distance of the Old Red Sandstone forming the floor or base of the Coal-measures. Therefore, to say that where *Spirorbis* limestone was found in boring or sinking that the thick coal-seam, or any coal-seams, would be found below, was a most erroneous conclusion; and he hoped that no mining engineer would apply the observation to the Forest of Wyre or any other coal-field.

* *Trans. Fed. Inst.*, vol. iii., page 60, Fig. 2, plate VI.

Prof. LAPWORTH (Birmingham) said that most geologists were agreed as to the geological date of the red rocks found in the Hamstead shafts, namely, that they were intermediate in position between the richest Coal-measures and the Trias. He was glad that Mr. Jones had directed attention to the doubtful nature of the *Spirorbis* limestone as determining the existence of workable Coal-measures below it. What could be said was, that in certain parts of England it was exceedingly likely that when *Spirorbis* limestone was found that the thick coal-seam or its representatives might be found below, but along the southern margin of the Midland coal-fields, its occurrence was no index of the existence of the thick coal-seam or of any workable coal-seams below. He thought members might accept Mr. Meachem's results that the rise of temperature in depth at the Hamstead shaft was 1 degree for every 117 feet of depth.

Mr. W. SPENCER (Leicester) said that it would be interesting if some of the members would give their experience as to the effects of the pressure of the rocks at a depth of 1,800 feet upon brick-arching, etc. In his experience, brickwork had been crushed at a much less depth than 1,800 feet; he thought that the crushing would vary with the nature of the strata more than with the depth. He had known cases where, at a depth of 900 feet, bricks had been crushed, and in others, at 1,200 feet, they had not been crushed. In some cases he had found that blocks of wood stood much better than brick of the hardest kind.

Mr. T. FORSTER-BROWN said that he gathered, from Mr. Sopwith's remarks, that in the northern part of the coal-field a portion of the Coal-measures was being worked at Walsall Wood colliery (which appeared to lie in the same range as Hamstead colliery), and that a fault dipping eastward had been proved of very large extent to the east of the Walsall Wood colliery. It would be very interesting to know the direction of that fault, and whether it approached the Hamstead colliery, and elucidated the probabilities of the eastern extension from that colliery. He might mention, with regard to the pressure of the overlying rocks, that in South Wales where there was a great pressure at a depth of 2,200 feet, at half that depth there was not a corresponding pressure.

Mr. F. G. MEACHEM wrote in reply to Mr. Sopwith and Mr. T. Forster-Brown's remarks that he had carefully gone into the matter of the eastern faults, but had not intended to refer to the question until farther explorations had been made in the gate-roads proceeding eastwards. The fault recorded on the maps of the Geological Survey as the boundary fault was but one of a series of step-faults to the east. At Sandwell colliery, the coal-seam rises west by a succession of steps to within 600 feet of the

surface, near Beeches Road, West Bromwich. At Hamstead colliery, the dislocation, while maintaining its step-like character, became more pronounced, hence (within a mile of the fault above-mentioned) the thick coal-seam was found at a depth of 2,100 feet, so it was evident that there was a step-fault of 2,100 feet downthrow east in a distance of one mile from west to east. At Hay Head, the limestone is found at the surface faulted against the red rocks, and Barr Beacon belongs to this series (probably Bunter), so that at this point there is a fault which may have a throw of 2,400 feet. Farther to the north, at the Cannock Chase collieries, No. 5 pit, the deep coal-seam is found at a depth of 459 feet, and at a farther depth of 300 feet, or a total depth of 759 feet in all, the Silurian floor of the coal-field will be reached. If the red rocks faulted against the Hay Head limestone have a throw of 2,400 feet to the east, and the Silurian beds at the No. 5 pit of the Cannock Chase collieries are 759 feet below the surface, the writer is of opinion that the Coal-measures will be found at a depth of 1,500 feet below the level of the coal-seam in the above-mentioned pit. Consequently the deep coal-seam will probably be found in a series of steps, and may be regained in its integrity at a distance of about 1 mile east from the present explorations. The Walsall Wood colliery has already gone down to a depth of 1,500 feet on one of these steps. These step-faults are possibly the result of an earth-wave running from west to east. In the long roads going east at Hamstead colliery, the effects of this wave are plainly visible, and farther eastward the wave elongates with less rise and fall, showing that the eastern termination of the troubled ground is being approached. A similar wave will probably be found to exist to the east of the Cannock Chase coal-field. The writer has had an opportunity of studying the Warwickshire coal-field, and he is of opinion that workable coal-seams will be found over the whole district intervening between the South Staffordshire and Warwickshire coal-fields. The pits in this future coal-field will vary in depth from 1,500 to 2,100 feet. Farther east there is a fault in the Trias passing from the Lickey Hills by Washwood Heath, Erdington and Sutton Park, which will throw the thick coal-seam to a greater depth to the east, but as there is a thinning out of some of the beds, the depth may possibly be reduced. The writer's remarks as to the *Spirorbis* limestone were strictly confined to the district to the east of the boundary-fault, and he is of opinion that his remarks will be found to be correct.

The PRESIDENT proposed a vote of thanks to Mr. Meachem for his paper.

Mr. M. H. Mills, in seconding the vote of thanks, regretted that the members resident in the district had not given fuller information as to the eastern extension of the coal-field.

The resolution was carried unanimously.

The President said that the members were about to consider several papers on canals written by gentlemen specially competent to deal with the subject. Probably some of the members might not have much technical knowledge concerning canals, but it did not require such knowledge to be able to appreciate the great importance of all means of transport to an industry such as the mining industry of this country, which produced 200,000,000 tons of minerals annually—cheap and efficient means of transport were to it of vital importance. The question of cheap transport assumed additional importance in times of depressed trade, and the South Staffordshire coal-field was served by canals to a greater extent than most others, so that both the time and place of this meeting seemed specially appropriate for the consideration of these papers. The inland navigations of this country appeared from various causes to have been greatly neglected since the advent of railways, and in this respect we were said to lag behind many European nations and the United States of America. Various reasons were assigned for the present inefficiency of inland waterways, one of which was the effect of railway control over a considerable portion of them, and in so far as it eliminated competition this seemed to be a natural consequence of such control. Another cause was the want of uniformity of gauge in the construction of canals, which must be fatal to the efficiency of the system as a whole. The adoption of some form of mechanical haulage also seemed essential to the complete efficiency of transport by canals. The only effectual remedy for the present state of affairs would appear to be the creation of some controlling authority over all the canals of the country. These and many other aspects of the question would be treated by the writers of the papers, and he thought that the reading of those papers, and the discussion thereon would afford valuable information on the important subject of the inland navigation of Great Britain.

The following paper by Mr. Urquhart A. Forbes on "The Relative Progress of Railways and Waterways," etc., was taken as read:—

To illustrate Mr F. G. Meachem's Paper on "The Search for Coal," &c.

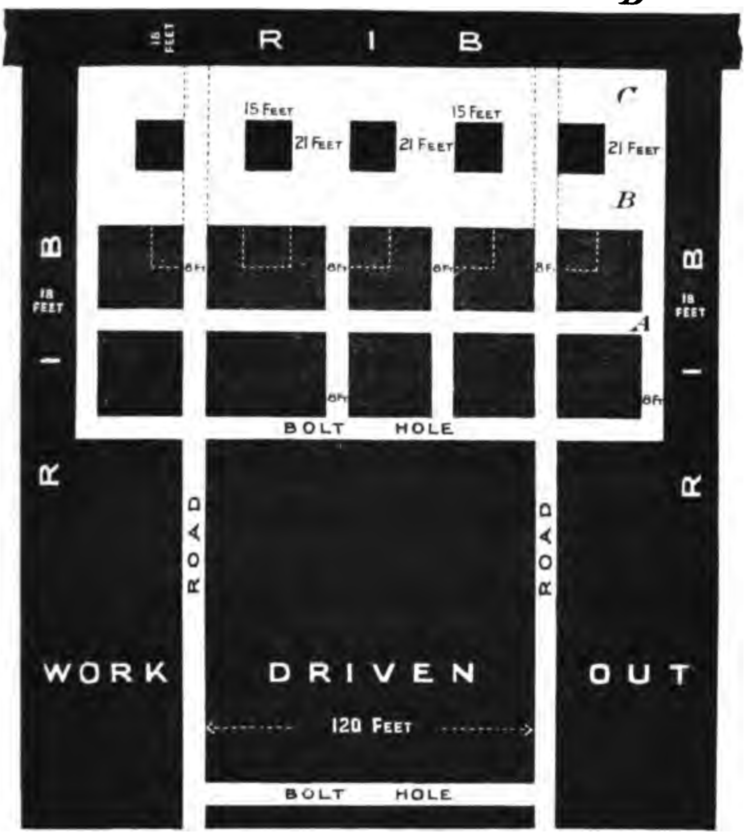
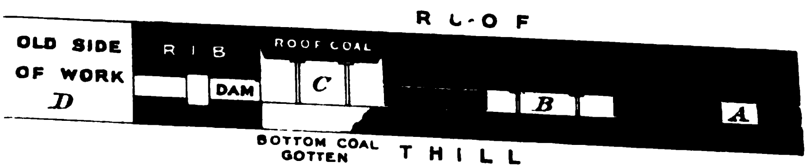


Fig. 1.



DIAGRAMMATIC SECTION, SHEWING POSITION OF WORKINGS IN THICK COAL-SEAM.

Fig. 2.

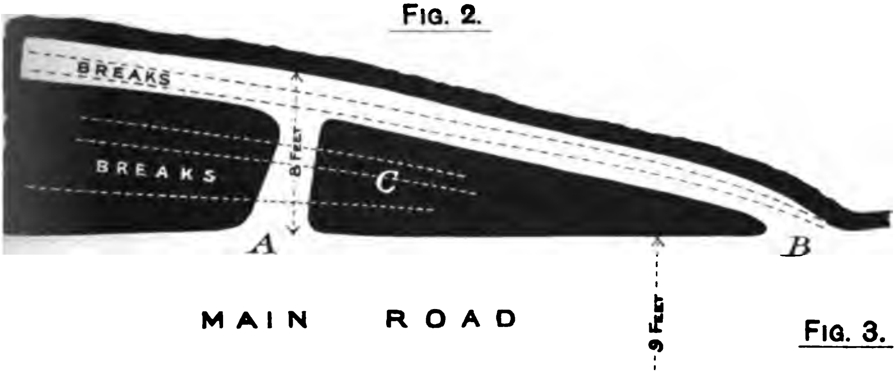


Fig. 3.

THE RELATIVE PROGRESS OF RAILWAYS AND WATERWAYS, AND THE METHODS SUGGESTED BY ITS CONSIDERATION FOR PROMOTING THE ARRESTED DEVELOPMENT OF THE LATTER.

BY URQUHART A. FORBES.

It is somewhat curious, and is certainly to be regretted, that in an age so fruitful in historic research as the present, the history of the development of our transport system—of which the arrested development of our waterways would form one of the most interesting chapters—has yet to be written. The practical importance of the subject must be generally admitted. Its records date back to the time when Britain was for four centuries a Roman province. The inventions connected with it have, by abridging distance, contributed more, as Lord Macaulay pointed out, towards the advancement of civilization than any others save those of the alphabet and the printing-press. And, lastly, it has been the chief means of proving to the world that distribution is one of the most essential branches of production, and not a separate and co-equal work with it.

This important fact, which is very clearly demonstrated by the Duke of Argyll in his valuable work on *The Unseen Foundations of Society*,* and of the practical recognition of which the share taken by manufacturers and traders in the promotion of the Manchester ship-canal affords a striking illustration, appears so self-evident that its statement may seem to be a mere truism. It is now apparently so obvious that the most abundant harvests and the largest stores of manufactured goods are valueless unless they can be rendered accessible to those who need them, that it is hard to realize that this fact was only very partially grasped by the earlier political economists, and has only been brought home to the general public through the enhanced powers of distribution which the development of transport has conferred on the trader, and without which he would be utterly unable to meet the demands for products of all kinds from our vast and ever-increasing population. History, however, shows that,

* Page 457.

though the development of transport by breaking down the barriers of time and space appears to be gradually producing, as it certainly has done among nations, more harmonious relations between the producer, the distributor, and the consumer, these relations have hitherto always been hostile, if not belligerent, and that the efforts of the State to adjust the balance between their conflicting interests have generally resulted in the arrangement of a sort of "three-cornered duel."

In Edward III.'s reign, for instance, we find the State, with the best intentions, endeavouring to suppress the distributor in order to protect the supposed interests of the producer and the consumer, by enacting that the publicans of Yarmouth were to make no more wholesale bargains with the fishermen, while the latter were to be assured of the full prices obtainable in an open market. Though, however, everything was to be regulated by a supposed spirit of equity embodied in a law, the plan broke down completely in four years. The fishermen could not leave their boats and nets to attend an open market, while the "hated middlemen," who were found to have discharged a function which the first producers were unable to discharge for themselves, could no longer count on the profits which alone could compensate them for dealing in a very perishable article. They had, in fact, produced one of the most valuable products, namely, distribution, and the king and Parliament, with a courage not to be expected from a government of the present day, acknowledged their mistake and repealed the benevolent law.* The growth of trade gradually forced the State to recognize that the trader in his capacity of distributor was not only indispensable to the original producer, but was also worth encouraging on his own account, and it then began to confer on him special privileges, such as those contained in the charters granted to the trading-guilds and companies of the Middle Ages. When the necessity for increased facilities of transport called into being a new branch of distribution which, like the first—that of wholesale and retail trade—and like the majority of our most valuable institutions, originated in private enterprise, the State pursued the same policy. It had now, however, to deal with new and more complex conditions, owing, on the one hand, to the rights of the owners of the land proposed to be appropriated for purposes of transit, and, on the other, to the extensive powers which it was necessary to confer on those who undertook to meet the needs of the public in this respect. The new distributors, the constructors of our highways by road, by water, and by rail, instead of being treated as pernicious and unnecessary—as were the original

* *The Unseen Foundations of Society*, pages 87 and 529.

distributors, the traders, in Edward III.'s reign—therefore obtained from the State important privileges which have been a constant source of friction between them and the consumer, the producer, and their co-distributors, the traders. And in addition to this, the competition for popular support and State patronage has naturally generated a spirit of hostility between railway companies and canal companies, which might not improbably have been also equally strongly developed between both of these and turnpike trustees, had not the abolition of turnpikes prevented highways by road from being utilized for the purposes of a remunerative "carrying trade" by privileged corporations.

The State doubtless never originally intended that the privileges, which it thus granted to private enterprise, and without which our transport system could never have been developed, should be permanent. As regards highways by road, the abolition of turnpike trusts is a proof of this. With respect to railways, we have equally strong evidence in the provisions, still unrepealed though never enforced, of the Act of 7 and 8, Vict., c. 85, based on the report of a committee of 1844, of which Mr. Gladstone was chairman; first, for the revision of the scale of tolls of railways if after twenty-one years from the passing of the Act for the construction of any future railway the profits should exceed 10 per cent; and, secondly, for the purchase by the Treasury at any time after expiration of the said twenty-one years of any such railway in the name and on behalf of Her Majesty.* That there is, so far as the writer is aware, no such provision in any Act relating to canals may not improbably be explained by the fact that they had not assumed sufficient importance at the time when they were superseded by railways to induce the Legislature to consider the advisabilty of either curtailing the powers of the companies or of purchasing their undertakings. As, however, it is always liable to be influenced by some temporarily dominant interest, the State can never be expected to be a thoroughly impartial, and still less an infallible tribunal. Under the fascination of railway enterprise, it not only speedily abandoned the good intentions which it had announced in the statute above referred to, but also allowed the railway companies to obtain control over more than half of the inland navigations of England and Wales, and thus reduced canal companies to what physiologists term a "state of suspended animation."

The action of the railway companies in this respect was undoubtedly in many cases of questionable legality, and it is some satisfaction to reflect that, though by their adroit manipulation of the waterways over

* Sections 1 and 2.

which they have obtained command, they have succeeded, as Mr. Conder forcibly expressed it in his evidence before the Select Committee of 1883 on Canals, "in strangling the whole of the inland water-traffic," their selfish policy has considerably interrupted their own lucrative and legitimate trade.* It would, however, be as unfair as it seems unwise to lay the whole blame for the present condition of inland navigation, for which the canal companies themselves are largely responsible, upon the railway companies' shoulders. It must always be remembered, in considering the competition between the two, that the canal companies had the advantage of being the first in the field. As early as 1792, the premiums of single shares in companies had reached such figures as £155 (Leicester), £350 (Grand Trunk and Coventry), and £1,170 (Birmingham).†

In 1806, we find the *Times* commenting with admiration on the fact that troops were being transported by canal from London to Liverpool *en route* for Ireland in only seven days. By 1830, five years after the opening of the Stockton and Darlington line—the birth-year of the railway system—£14,000,000 had been expended in constructing 4,332 miles of waterways, which furnished twenty-one through routes between London and the manufacturing districts. Never had private enterprise more brilliant prospects, and yet by 1846, though canals, such as the Oxford, the Coventry, and the Trent and Mersey, were producing dividends of 25, 26, and 30 per cent., we find their proprietors actually putting pressure upon railway companies to compell them to purchase their undertakings. The whole nation seems to have been carried away by the railway mania, and to have abandoned the costly and admirably designed system of water-communication with which it had been provided as no longer worthy of consideration. With a few exceptions, such as the Leeds and Liverpool and the Aire and Calder canals, the remunerative nature of which still continues to justify the wisdom of their promoters,‡ capital was everywhere withdrawn from canals to be invested in railways. During the three years, 1845, 1846, and 1847, the railway companies were permitted, if not indeed encouraged, to purchase 948 miles of waterways, a total subsequently increased to 1,717. The mileage of the waterways owned by the 63 independent canal companies is now reduced to 2,486, while their capital, including Government grants to Scottish and Irish canals, is only £30,656,000, more than half of which must be credited to

* Appendix 11, page 238. † *Gazette*, August, 1792.

‡ See as to the expenditure and enterprise with regard to these canals, a paper contributed by Mr. Edward Lloyd to the Conference on Canals, 1888, on "Inland Navigation in Great Britain." *Report of the Conference on Canals, etc., Society of Arts*, pages 30 and 31.

a single undertaking, the Manchester ship-canal. The mileage of the railways has, on the other hand, risen from 6,890 in 1851 to 20,646 in 1893, and the total capital of the railway companies from £248,240,896 to no less than £971,323,353.

It must be admitted that the results of the competition between railways and canals, as shown by the above comparison, are not encouraging to those who, realizing their value, desire to see the latter placed on such a footing as to form a counterpoise to the undue influence of the former. But, uphill though it be, there are good reasons for refusing to abandon the struggle as hopeless. That it is hopeless to attain success by assailing the railways through Parliament seems indeed undeniable. Canal companies lost their "Parliamentary influence," as a matter of course, when the public deserted them fifty years ago; while, leaving out of consideration the large proportion of the nation pecuniarily interested in the prosperity of the railway companies, and the members of both Houses of the Legislature included in the number, fifty members of the Upper and one hundred and thirty, or nearly one-fifth, of the members of the Lower House are officially connected with them. Though the traders have secured a re-adjustment of the railway rates under the Railway and Canal Traffic Act they have derived no appreciable benefit from it; and as the railway companies, by destroying the efficiency of waterways, have secured an excess of traffic, which is already a serious hindrance to their practical utility, no amount of reduction in their charges would enable them better to meet the urgent demands of the traders for increased facilities of transport. And though such a reduction might very well go far to ruin the railway companies, it is manifest that it would in no whit increase the efficiency of the canal companies; while, having regard to the outlay necessary before our canals, the majority of which were constructed on the antique methods of the last century,* could be rendered remunerative, there is no reasonable ground for anticipating that any Government could be induced to sanction their purchase by the State, or that, if bold enough to do so, it could afford to throw them open to the public free of toll.

State aid in either of these forms would seem to be a useless retrogression to the unsound policy, which Edward III.'s Parliament found to be so entirely impracticable when attempted in the interests of the Yarmouth fishermen five centuries ago. On the other hand, the successful completion of the Manchester ship-canal shows what can still be effected

* "Canal Engineering," by Mr. L. F. Vernon-Harcourt, *Report of the Conference on Canals*, *Society of Arts*, 1888, page 3, *et seq.*

by private enterprise when supported by a great and wealthy municipality, and there seems little doubt that it is on energetic and well-directed private enterprize, and on it alone, that those who are striving for the resuscitation of our waterways should rely. It is after all to this source that the success of the railway movement is to be traced. Those who are naturally jealous of the influence over the Legislature which this success has obtained for the railway companies are apt to forget the difficulties with which they originally had to contend, not only through the strenuous opposition of the landed interest and the distrust of the public for the new form of transport, but also through the general ignorance, in which they themselves necessarily shared, which at first prevailed with regard to the true nature and capacity of the railway system. The chief methods by which they have triumphed over this last class of difficulties, and have brought their system to its present perfection appear to be:—(1) By the construction of through routes controlled by single authorities; (2) by the organization of a carrying-trade on these routes; and (3) by the establishment of the railway clearing-house; and as all of these methods seem equally applicable in the case of waterways, it may be useful to consider how far they can be utilized for reviving the development of the latter.

1. As regards through routes, it is interesting in connexion with the present conference to recall the facts that the success of the railway system dates from the opening of the line from Birmingham to London in 1838, and that the bill authorizing its construction was the subject of the greatest parliamentary conflict in the history of railways, and involved an expenditure of £70,000. Within four or five years of its passing, the foundations of all the great trunk-lines were laid, and their successful development affords a good illustration of the truth of Sir Arthur Cotton's contention that it is communication which makes traffic, and not, as is often erroneously stated, traffic which makes communication.* Not only do towns spring up everywhere along the great lines, but those too far removed to benefit by them, find their trade diverted to others which have the advantage of being close to them—as, for instance, in a large tract of the Cotswolds, with which the writer is acquainted, where not a few of the market towns have suffered in this way owing to their

* *Report of the Select Committee on Canals*, 1883. Appendix 21, page 287. "On a certain line, in its natural state, 1,000 tons a year may be carried on men's heads; if a rough road is made, 10,000 tons may be carried by pack animals; if a good wheel road is opened, 100,000 tons may be moved; if a railway, charging 1d. per ton-mile, 500,000 tons; if a steamboat canal, carrying at 20 ton-miles per 1d., 5,000,000 tons."

distance from the Midland and Great Western railways, which, meeting at Bath and at Cheltenham, completely encircle it. Owing to the fact that they have all acquired control over the whole length of their through routes, the great railway companies have been able to "capture" the traffic of the entire territory that they traverse; but, though there are, as already stated, twenty-one through routes by water in England and Wales, there is not one which has had the advantage of being under one governing body, and all, consequently, bristle with inconveniences calculated to drive away traffic even when it is abundantly to be found within easy reach of them.

Two typical instances may be cited in proof of the contrast between railways and canals in this respect. Three years ago, the Lancashire, Derbyshire, and East Coast Railway Company projected a line from Warrington docks, on the Manchester ship-canal, to Sutton-on-the-Sea, between Grimsby and Boston. This through route between the Atlantic and North Sea coasts is almost parallel in direction to that provided by the Great Western Railway between London and the Bristol Channel, and about the same length, 118 miles. Both lines pass through agricultural, coal-producing, and manufacturing districts containing various populous centres, and both occupy a similar position as to competition with waterways, there being three through routes by water from Liverpool to Hull and three from London to the Severn ports. In the case both of the northern and southern cross-country waterways, each of the through routes begins in a common tidal estuary and, after diverging to traverse its special tract of country, reunites with the other two in another common estuary; and it might at first sight seem that their threefold nature would give them an advantage over the railways in the competition. When we examine the conditions under which traffic is carried on, however, the advantage enjoyed as to through routes by a single competing railway (handicapped though it be by the conveyance of passengers which take precedence of goods), is at once apparent. The first of the northern through routes commences with the Leeds and Liverpool canal and joins the Aire and Calder navigation, reaching the estuary of the Humber after a course of 180 miles. The second—by the Mersey, the Duke of Bridgewater's canal, the Rochdale, Calder and Hebble, and Aire and Calder canals—has a length of over 150 miles; while the third, which is a few miles shorter, runs from the Mersey *via* the Duke of Bridgewater's, Rochdale, Ashton, Huddersfield, Sir John Ramsden's, and Calder and Hebble to the Aire and Calder canals. In addition to the navigation authorities of the

Mersey and the Humber rivers, this through route system of waterways is controlled by eight different companies, amongst whom there is the keenest competition. On the first route, the Leeds and Liverpool canal, the gauge of the locks is 70 feet by 16 feet with a draught of about 4½ feet, while on the Aire and Calder it is 112 feet by 22 feet with a draught of 9 feet. On the last and shortest route, a consignment of goods has to traverse ten distinct waterways, the gauges of locks on which range through various grades from 50 feet by 14 feet by 4·6 feet on Sir John Ramsden's canal to 212 feet by 22 feet by 9·6 feet on the Aire and Calder. The three through routes from the Thames to the Severn are in like manner governed by two conservancy authorities, two town corporations, one railway company, and seven canal companies, and exhibit the same interesting variety as respects the gauges of their locks; and as similar conditions prevail in every through route it is no matter for surprize that the vexatious and injurious delays which they entail should drive the trader to employ the more costly means of transit provided by railways. These defects of our system of inland navigation can only be remedied by placing all the independent links which make up each through route under one authority, and it is cheering to note that a step in this direction was made last year by the Grand Junction Canal Company and by the Grand Canal (Ireland) Company, the former of which purchased the Grand Union, the Leicestershire, and the Northamptonshire Union canals, and the latter the Barrow navigation. When carried on in this way by individual companies this process of consolidation must, however, of necessity be slow, and those who desire to see waterways placed on the footing which they deserve must agree in hoping that it may be accelerated before long by the realizations of such schemes as that for connecting Birmingham with the German Ocean by means of the Trent and the still more important one for uniting it with London described by the late Mr. Marten at the Conference on Canals of 1888.*

2. The gradual development of opinion among railway companies with respect to the carrying-trade is equally worthy of the attention of canal companies. At their first construction, railways were regarded as "land canals," and the Legislature passed Acts authorizing any person to run his trains over lines on payment of the requisite tolls, and empowering owners of adjacent lands to make branch lines having free access to the railways, and lords of manors to erect wharves, and use such portions of the lines as passed through their lands free of charge. The companies

* *Report of the Conference on Canals, Society of Arts*, page 63.

themselves declared that it was against their wish, and would be against their interest to attempt the carriage of goods and passengers, and that they were desirous of being toll-takers only. It is needless to say that the beginning of their prosperity dates from the time when they overcame their repugnance in this respect, but as late as 1840 private carriers were still found competing with the companies on some lines, such as the Grand Junction and the Great Western.

The witnesses examined on this subject by the Select Committee on Canals were divided in opinion, some, like Mr. Clark, of Wolverhampton, advocating that carrying on canals should be entirely entrusted to private traders, and others, such as Mr. Lloyd, manager of the Warwick canals, and Mr. Bartholomew, engineer of the Aire and Calder navigation, strongly urging the advisability of canal companies acting as carriers. The statement of Sir Frederick Peel, chairman of the Railway Commission, that, owing to carrying on the majority of canals being done by private traders, the commissioners could only deal with complaints as to the conveyance of traffic where they had reference to the tolls for the use of the waterway, seems, however, to give additional weight to the latter view. It appears, moreover, to be largely justified by the evidence as to the relative numbers and commercial importance of the carrying and solely toll-taking canals furnished by the returns made to the Board of Trade in 1890, under section 39 of the Railway and Canal Traffic Act, 1888.*

Of the canals of the United Kingdom, which have a total mileage of 3,813 miles, only eighteen with a total mileage of 1,380 act as carriers, ten of which—six in England, one in Wales, and three in Ireland—are independent, while the remaining eight, which are all in England, are owned by railways. Though the mileage of the seven independent canals in England and Wales is 200 miles less than that of the eight owned by railway companies, the revenue earned as carriers by the former is more than double that owned by the latter, £433,006 as against £199,042, as is also the amount taken in tolls. If the three independent carrying canals in Ireland be added, the revenue of the ten independent canals as carriers will be found to be £486,198 as against £199,042 earned by the eight railway-owned canals of the United Kingdom, the mileage of the former being 687 and of the latter 693, while their respective earnings as toll-takers are £221,344 and £80,804. An examination of the individual earnings of the canals in the two classes shows that while, as might be ex-

* This appears to be the only return published on the subject, and the writer is informed that the Board do not intend calling for any other at present.

pected, the revenue earned by the railway-owned canals as toll-takers is, with only two exceptions,* considerably above that earned by them as carriers, exactly the reverse is the case, with one exception,† with the independent canals. Thus the Aire and Calder earned £121,775 as carriers and only £67,835 from tolls; the Leeds and Liverpool £94,464 as carriers as against £43,367 from tolls; and the Trent Navigation £14,115 as carriers and only £1,492 from tolls; while the total revenue of the ten independent canals from freight as carriers is £486,198, and that earned by tolls £221,344. Lastly, if we compare the profits earned by canals acting as carriers with those, whether acting as carriers or not, taking tolls, we find that the total earnings of the eighteen carrying canals of the United Kingdom amount to more than two-thirds of those earned by one hundred and twenty-six toll-taking canals, £685,240 as against £998,844, though the mileage of the former is only 1,380 miles‡ and that of the latter 3,811 miles.

Setting aside the complex question as to the advisability of traders competing with companies as carriers on canals, which is, of course, governed in many cases by the conditions of the incorporating Acts, the above facts seem to show that where—as in the case of the Aire and Calder, one of the most prosperous canals—a canal company controls an important through route, the carrying-trade may be made as remunerative on canals as on railways.

3. The desirability of a clearing-house for canals is so obvious and has been so generally admitted, that it is scarcely necessary to enlarge on the benefits which the railway companies have derived from this branch of their organization. In the case of the latter, its establishment seems to have followed as a necessary consequence of the foundation of the great trunk-lines, and it can scarcely be doubted that if some half dozen of our through routes by water were made worthy—which they can scarcely be said to be now—of the appellation, and a brisk carrying-trade were developed upon them, it would lead to a similar result. The establishment of a clearing system for canals was expressly provided for under section 44 of the Railway and Canal Traffic Act, 1888, and its merits have been fully demonstrated in a report to the Lancashire and Cheshire Conference on Railway and Canal Rates by their counsel, Mr.

* The Chesterfield canal and the Shropshire Union canals. It is to be noted that the latter is not an ordinary railway company, but a canal and railway company.

† The Rochdale canal, which was at one time leased to railway companies and became independent about 1875.

‡ Tables showing these details are contained in the Appendix.

Waghorn, in the autumn of 1892, as well as in two able articles published in the November and December numbers of the *Canal Journal* (a periodical which unfortunately has ceased to exist) for that year. Until it is created neither canal companies nor traders can have the full benefits of intercommunication, and it would doubtless serve, as the railway clearing-house has done, as a means for settling disputes in a friendly spirit without having recourse to law. It would thus provide a basis for securing combination and concerted action among canal companies, and without these it seems hopeless for them to attempt to compete with railway companies, which are constantly manifesting an increased tendency to recognize the benefits of co-operation.

In concluding this paper, for the length of which an apology is due to the members, the writer may reiterate the conviction that private enterprize fostered by means of co-operation, not only between the companies themselves, but also with the trading community, which is scarcely less interested than canal-owners in making canals a real counterpoise to railways, offers the only efficacious remedy for renewing the arrested development of our waterways.

APPENDIX A.—CANALS DOING BUSINESS AS CARRIERS, SHOWING THE COMPARATIVE REVENUE DERIVED FROM FREIGHT AS CARRIERS AND FROM TOLLS OF INDEPENDENT CANALS, AND CANALS OWNED BY RAILWAYS RESPECTIVELY.

INDEPENDENT CANALS.

Name.	Mileage.	Revenue from Freight as Carriers.	Revenue Derived from Tolls.
ENGLAND AND WALES.		£	£
1. Aire and Calder navigation ...	93	121,775	67,835
2. Glamorganshire canal	25	4,111	4,053
3. Leeds and Liverpool canal ...	143	94,464	43,367
4. London and Hampshire canal ...	37	1,268	78
5. Manchester ship-canal	75	192,479	76,332*
6. Rochdale canal	34	4,794	19,394
7. Trent navigation	68	14,115	1,492
	475	433,006	212,551
SCOTLAND. None.			
IRELAND.			
1. Barrow navigation	43	5,032	1,992
2. Grand canal	165	47,600	6,801
3. Strabane canal	4	560	Nil.
	212	53,192	8,793
Total of the United Kingdom. .	687	486,198	221,344

CANALS OWNED BY RAILWAYS.

Name.	Mileage.	Revenue from Freight as Carriers.	Revenue Derived from Tolls.
ENGLAND AND WALES.			
London and North-Western Railway Company—		£	£
1. Shropshire (Coalport) canal ...	20	70	455
2. Lancaster canal	72	2,087	7,094
Manchester, Sheffield, and Lincolnshire Railway Company—			
3. Ashton canal	70		
4. Peak Forest canal	70	10,908	12,981
5. Macclesfield canal	70		
6. Chesterfield canal	72	2,793	1,442
North Staffordshire Railway Co.—			
7. Trent and Mersey navigation	119	4,238	53,454
Shropshire Union Railway and Canal Company—			
8. Shropshire Union canals ...	200	178,946	5,378
	693	199,042	80,804
SCOTLAND. None.			
IRELAND. None.			
Total of the United Kingdom...	693	199,042	80,804

* Including dockage.

APPENDIX B.—COMPARATIVE MILEAGE AND REVENUE OF CANALS ACTING AS CARRIERS, AND OF CANALS ACTING AS TOLL-TAKERS.

Country.	Canals acting as Carriers.			Canals acting as Toll-takers.		
	No. of Canals.	Mileage.	Revenue as Carriers.	No. of Canals.	Mileage.	Revenue from Tolls.
ENGLAND AND WALES.			£			£
Independent canals	7	475	433,006	61	2,025	741,096
Canals owned by railways ...	8	693	199,042	50	1,024	174,570
	15	1,168	632,048	111	3,049	915,666
SCOTLAND.						
Independent canals	None	—	—	2	69	9,429
Canals owned by railways ...	None	—	—	2	84	48,729
	—	—	—	4	153	58,158
IRELAND.						
Independent canals	3	212	53,192	10	513	20,912
Canals owned by railways ...	None	—	—	1	96	4,108
	3	212	53,192	11	609	25,020
Total of the United Kingdom ...	18	1,380	685,240	126	3,811	998,844

The following paper by Mr. J. Stephen Jeans on "The Comparative Conditions and Costs of Transport by Railway and Canal," was taken as read:—

THE COMPARATIVE CONDITIONS AND COSTS OF TRANSPORT BY RAILWAY AND CANAL.

BY J. STEPHEN JEANS, MEMBER OF THE ROYAL INSTITUTION OF GREAT BRITAIN, M.I. AND S. INST., F.S.S., AUTHOR OF "RAILWAY PROBLEMS," "WATERWAYS AND WATER TRANSPORT," ETC.

The subject of canal transport is one that must always be present to the coal-owner, the colliery manager, and all who are in any way, directly or indirectly, concerned in the great business of transportation—a business that yields to the railway companies of this country, in respect of mineral traffic alone, about 16½ millions sterling a year, or nearly one-third of the total value of the coal output at the pits' mouth in the year 1893.

In these days of close competition, both home and foreign, it is natural that traders should seek by every means in their power to come to closer quarters with the railway companies in the matter of cost of transport. To avoid the payments entailed upon them under this head, many of the largest colliery owners have constructed their own railways or tramways, have built their own ports, harbours, or docks, have established their own lines of steamers, and have undertaken other enterprises that have more or less enabled them to become independent of the great main lines of railway-communication, and to place their produce on the market at the lowest possible cost. Nevertheless, the difficulties of reaching some of the principal markets are still so serious as to call for the most anxious care and solicitude. The average cost of coal at railway-depôts in the metropolis is much more than twice its cost at the place of production. The average cost of coal and coke at ironworks on the west coast is nearly twice as much as the cost at the pits and ovens in South Durham, and for that reason the iron and steel industries of West Cumberland and North-West Lancashire have long been in a more or less unsatisfactory condition. The low cost of placing coal f.o.b. in Cardiff docks has exalted that port to the foremost place among the great coal-shipping ports of the world, and has secured for it an unique position in reference to volume of exports. The high cost of coal has destroyed the manufacturing activity of numerous centres of population that were formerly hives of industry, including even the metropolis itself. In short, the cost of

coal very largely determines the prosperity or otherwise of communities, and the cost of coal, in its turn, is determined by the difference between the prices charged at the place of production and at the place of consumption.

The traders and manufacturers of this country have for many years endured a permanent and apparently irremovable grievance in the high cost of railway transport. This grievance formed the subject of many days of discussion and enquiry while the maximum schedules of rates and charges and the proposed statutory classification under the Railway and Canal Traffic Act of 1888 were before the Board of Trade, and afterwards before the hybrid committee by whom they were ultimately fixed. The traders submitted many lists of rates and charges, tending to show that although the coal traffic was the backbone of the business carried on by the railway companies, the rates charged for carrying it on were much higher than they should be, rising sometimes for short distance traffic to 1½d. per mile, or six times as much as it ought to be. Even the London coal traffic was seldom carried for less than ½d. per mile, although the cost of the service, excluding interest on capital, was considerably less than one-half of that amount.

The traders have long sought relief from the high charges on coal traffic by casting about for ways and means of more fully utilizing canal navigations. Drowning men clutch at straws, and we can hardly regard the existing system of canals in this country as much better than straws, and those too of the weakest. A few of the canals are able to carry a relatively considerable volume of traffic, but as a rule, the canal-system makes a wretchedly poor show alongside of the railways, alike in the matter of extent and value of traffic, facilities, methods, and working arrangements generally, while the writer is by no means certain that they offer substantial inducements in the matter of cheaper transport.

The city of Birmingham, in which we are now assembled, has not only been largely the cradle of the canal system, but is, even to this date, a foster-mother to water-navigation for heavy traffic. The Birmingham canal navigations are among the most extensive in the whole country, and carry altogether nearly eight millions of tons of traffic, which is more than three times the tonnage carried by the Aire and Calder canal, the next most important system. Nor is the Birmingham system without interest from other points of view. The Netherton and Dudley tunnels—the former 9,081 feet and the latter 9,516 feet in length—are sufficiently notable to be classed among the great engineering works of an earlier day, and so also with the Lappal tunnel which extends to 11,385 feet in length.

These works must have taxed the resources of the constructive minds of the last century much more severely than more wonderful works would be likely to do at the present day. So also with the reservoirs that feed the Birmingham canal system, six in number, and one of them with a capacity of 105,000,000 cubic feet.

According to the Canals and Navigations Returns for 1888, the total capital paid up and raised from all sources in respect of the canals of the United Kingdom, not belonging to railway companies, was 24¼ million pounds, or about £9,300 per mile. Some 1,204 miles belonging to railway companies do not show the cost, which is mixed up with that of the undertakings to which they belong, but if we assume the same average, which is likely to be rather over the mark, we should have 11 millions more, bringing up the total capital outlay on the canal system to 35¼ million pounds, which coincides very closely with 20s. of capital per ton of annual traffic carried. Measured by the same test our railways should show a capital expenditure of about 300 millions sterling, whereas the actual capital outlay has been more than three times that amount.

If the canal system could provide for the same density of traffic it would manifestly be much the cheaper system of the two. But as it cannot do this, we are bound to assume that it labours under a disability which is not easily removed.

The canals of Great Britain are not only inefficient, but like most men and things that fail in efficiency, they are not over well rewarded in the matter of profits. The total net profits derived from the canals in the hands of private companies, as distinguished from railway companies was some £592,000, equal to the payment of a dividend of only 2·4 per cent. on the paid up capital. On the railway systems as a whole, the net receipts amounted in 1893 to £34,936,000 and was equal to the payment of 3·60 per cent. on the invested capital, the average for 1888 having, however, been 4·06 per cent.

Comparatively few people stop to enquire as to the amount of the toll which the railway companies are accustomed to take from the inhabitants of these islands in the form of transportation-charges. It now amounts to over £2 per head of the entire population. It is more than four times as much as the total local taxation of the kingdom. It is almost as much as the total amount of the national income for State purposes. It is more than the total value of the total mineral produce of all kinds, including coal. It is nearly as much again as the total rent of the country for agricultural purposes, and it is nearly a tenth part of the estimated income of every class of the community.

In order to pay a 5 per cent. dividend on the capital of the English railways, a sum of £2,600 would have to be earned per mile per annum, whereas a sum of less than £500 per mile would suffice to pay the like dividend on canal expenditure. Even so, however, it is important to bear in mind that the capital invested in our canals, as measured in this way, is almost as large as that expended on some important systems of railway mileage. The average expenditure on American railways, as ascertained by dividing the mileage constructed into the total amount of capital now entered against the system, works out to close on £12,000 per mile. Mr. Poor, the well-known railway expert, has stated again and again that nearly one-half of the total amount was pure water, and that up to a comparatively recent date the capital actually expended did not exceed £7,000 per mile, except in a very few localities.

The late Mr. E. R. Conder had perhaps an exaggerated idea of the extent to which the canal system of this country might be utilized, but he had no doubt as to the greater cheapness with which traffic could be carried by canals, as compared with railway transport. In a calculation which he submitted to the Select Committee on Canals,* he estimated that the actual cost of working the traffic carried on the railways of the United Kingdom was not less than 0·53d. per ton per mile, and to this he added 0·78d. per ton per mile in respect of interest on capital invested, making a total of 1·31d. per ton per mile for both items, and a total cost per 100,000 units of £587. On the other hand, he estimated that, with a similar volume of traffic, the cost of canal transport in England would only be 0·37d., including 0·11d. for interest on investment, or £154 per 100,000 units. In other words, he estimated that the cost of railway transport would be at least three and a quarter times as much as the cost of canal transport. Of course, the cost of carrying mineral traffic would in both cases be much less, although it is curious to note that the railway companies have never appeared to be over-ready to give exact information as to what that cost actually is. The late Sir James Allport, who ought to have known, as the manager for many years of the Midland Railway Company, stated that the cost of transporting mineral traffic on that system—assuming 42 trucks or 336 tons of minerals to a train—was 2s. 6d. per train mile, including everything,† which would, of course, bring down the actual cost of haulage to 0·089d. per ton mile, or 0·178d. per ton mile, including return empties. This is, in short, assumed to be a generally approximate figure for mineral traffic in English railway working. On

* *Report*, 1883, page 233.

† *Select Committee on Canals*, 1883, page 83.

three of the principal English railways, so far back as 1865, the ascertained cost of working mineral traffic varied from 2s. 6·6d. to 2s. 10·7d. per train mile,* while the cost per ton mile would, of course, vary with the extent of the paying load. The same figure was accepted by the late Sir George Findlay and other railway experts in giving their evidence before the Board of Trade Commission on Railway Rates and Classification in 1889. To this we must add the amount required to meet the interest charges on capital, which we have already shown to amount to £2,600 per mile of railway opened, but which we cannot easily apportion in relation to merchandize train-mileage, owing to the difficulty of separating the goods and passengers' apportionment of expenditure.

To an institution like The Federated Institution of Mining Engineers, which is mainly concerned in the production and distribution of coal, no question can be of greater importance than that of cheap transport of the mineral which it is the province of its members to produce and that of the public to consume. Unfortunately, in Great Britain, we are handicapped in this matter to a greater extent than is any other country of industrial importance. The last published report of the Inter-State Commerce Commission of the United States purports to show to what extent we are handicapped in the cost of transportation as compared with other and competing countries. It states that whereas the average ton-mile rate in the United States is under ½d. per ton per mile for all descriptions of traffic, the average rate for the United Kingdom is not less than 1¼d. per ton per mile, and the average for France and Germany comes in between the exceptionally low rates of the American railways and the exceptionally high rates of our own country.†

One of the differences that distinguish English railway administration, in its relations with traders from those of other countries, is the comparatively small reduction that has been made in railway rates and charges of late years, notwithstanding the great economies that more scientific and intelligent methods have enabled railway managers to undertake. This is a permanent and a just grievance with the large traders. Improvements in all mechanical appliances and methods, in systems of grading and permanent way, in the cost and efficiency of locomotive engines, in the consumption of fuel, in the control of trains by brakes, etc., which have enabled the numbers of men needed to safely

* *Report of the Duke of Devonshire's Commission on Railway Working.*

† It is, however, important to bear in mind that English railway statistics do not afford any data as to ton-mile rates, and the railway companies have always professed that they had not the information, so that the average given by the Inter-State Commerce Commission must be largely guess-work.

manage a train to be reduced—all these and other sources of economy should be reflected in the cost and incidence of railway charges, and so they are in all countries except our own. It is the same with the capital expenditure relatively to the mileage constructed. In Germany, France, Belgium, Italy, and most other countries, the average capital outlay per mile of line opened has been reduced during recent years, whereas in this country it has been not only sensibly, but enormously increased. Under these circumstances it is scarcely a matter for surprise that traders are discontented.

There is no record of the average distance over which mineral traffic is carried on either railways or canals. It is a pity that the Board of Trade, in getting out the returns of canal traffic, did not ask for particulars of the ton-mile traffic, and if they had also obtained some particulars of the descriptions of traffic carried it would not have been amiss, seeing that no details are available as to how much was minerals and how much took the form of other goods. It is, however, more than probable that three-fourths at least of the traffic carried on the canals was mineral traffic, while we know that 208 millions of the 293 millions carried on the railways in 1893 was mineral traffic. These things being so, it is interesting to find that the average receipts per ton carried on the canals was 1s., while on the railways it was 1s. 6d., showing, as far as they go, that mineral traffic is either carried for shorter distances on the canals or is subject to the payment of lower charges. It may be added that where the average gross receipts per mile of line open on the railways was £3,722, it was on the canals only £710 in England and Wales; and that while the proportion of expenditure to receipts was 57 per cent. on the railways (in 1893), it was 59·8 per cent. on the canals of England and Wales.

The United Kingdom, although liberally endowed by nature with facilities for shipment and with other obvious natural advantages, is quite destitute of the remarkable resources for inland transport possessed by some other countries, and more especially by the United States. In the latter country the southern coal-fields have access by the great Kanawha river to the Ohio and the Mississippi rivers, giving over 16,000 miles of inland navigation. On these rivers and their tributaries we meet with what we would like to regard as ideal coal rates. It is usual to tow coal cargoes from Charlestown to Cincinnati, a distance of 263 miles, for 1s. 0½d. (25 cents) per ton, excluding barge hire. From Charlestown to New Orleans the distance is 1,776 miles, and the rate for towing and hire of barge is 5s. 2½d., or 0·035d. per ton per mile. From Cincinnati

to the mouth of the Kentucky river at Louisville, a distance of 394 miles, the rate, including towing and rent of barge, is 2s. per ton. But on the Ohio river, the tow-boats often take from 18 to 34 loaded barges, or about 15,000 tons of live-load, which is a condition of things that does not and could not well exist in this country. In short, when we look at these American rates we can only wonder, envy, and think of the things that might have been.

It is, however, much the same, *mutatis mutandis*, with canal and railway traffic. In both cases the rates are very much below what we have any knowledge of in this country. The State of New York alone has expended some 70 millions of dollars, or roughly 15 million pounds on canal construction and improvement. In 1873, the average rate on the New York State canals per ton of traffic carried was 0·44d. per mile, but in 1881 the rate had dropped to 0·19d. per ton per mile, and after 1882, when the tolls were abolished, the rates were often lower still. These rates, low as they are, appear to be relatively high when compared with some of the rates paid on the railways of the same country. In 1892, the average ton-mile rate on the Philadelphia and Erie system was only 0·22d., and on the Chesapeake and Ohio, in the same year, the average was only 0·25d., on the New York Central it was 0·35d., on the Pennsylvania 0·28d., on the New York, Lake Erie and Western 0·30d., and on the Lake Shore and Michigan Southern it was only 0·29d. Some of the railways had, of course, a much higher average than those just quoted, but the official average ton-mile rate on the railways of the United States as a whole in 1890 and 1891 did not exceed 0·47d., while in 1893 the average was only 0·44d. per ton per mile. In the German Railroad Union for the same year the average ton-mile rate was 0·67d., to which figure it had fallen from nearly 1d. ten years ago. In Belgium the railway rates are much the same as in Germany, and in France they are close on 1d. as an average. In all these countries the railway rates have undergone considerable modification during recent years. In the United States, indeed, had the rates current in 1865 to 1869 been maintained over the last ten years the railways of that country, as a whole, would have earned £200,000,000 a year, or £2,000,000,000 for the whole period, more than they actually did earn. These immense figures indicate the great magnitude of the problem of cheap transportation. The reduction of rates on the American railroads between 1869 and 1893, on the traffic of the latter year, would represent an annual saving to freighters of considerably more than twice the amount of our total national expenditure, or nearly three times the amount of the total gross railroad earnings of this country.

It is only when we marshal and consider figures like these that we realize the vast importance to the trade of the country of the issues involved in this question. It is not for a moment pretended that the cases are parallel. We could not expect, under any circumstances, to have rates so low as those current in the United States, where the average haul is quite three times as much as in our own country, where the facilities are not nearly so abundant, and where the gradients over a large area are almost *nil*. But it is certainly of the utmost moment to our trade and commerce to learn that Germany, a country with much more nearly parallel conditions, has an average ton-mile rate of only 0·67d., or not more than one-half of that which is understood to prevail in Great Britain.*

It has probably not often occurred to the members of this Institution to consider what sort of millenium they would enter upon if we had the command of as cheap rates of transport as they have in the United States. With ½d. average ton-mile rate, our payments to the railway companies would fall from over £40,000,000 a year to less than half of that amount. In other words, our bill for transport would be reduced by a sum that would be more than equal to the aggregate value of our annual exports of coal and coke. This is a prospect that is manifestly too good to be realized. Its realization would practically mean the ruin of British railway investments, which now yield only about £35,000,000 of annual net receipts from all sources. The existing railway *régime* durst not attempt anything of the sort, even were they so minded, nor is it probable that, even with the cheapest conditions imaginable for railway transport, our economic circumstances could be brought to the same level as those of America. It would not be fair to forget that the conditions of working in the two countries are greatly dissimilar. In the United States, the average length of haul exceeds 110 miles, whereas in this country it is not more than 35 miles, if quite as much even as that. In the United States, again, the custom is to have very heavy train-loads, up to 2,000 tons, whereas in this country a load of 350 tons is rather exceptional. This, of course, means that in the United States the railway companies have relatively small handling expenses, and as they carry heavy loads for long distances, they can make use of very much larger waggons and trucks than we can, which saves tare and facilitates economical working.

* The writer is aware that the rates on coal traffic, both for London and for local consumption on a large scale, are often under ½d. per ton per mile, but we have to deal with the average of the whole country in both cases, and not with particular rates or classes of rates.

It is, however, quite on the cards that some economies could be introduced into the working of English railways, although the writer would not dogmatize on this point. The railway companies are naturally interested in working their traffic as economically as possible, consistently with providing traders with all the facilities which they require, and which are unquestionably afforded to them in a larger measure than is common in other countries. That consideration does not, of course, affect the traffic in which we are specially interested, so much as it does traffic of a more miscellaneous character. In the working of general traffic, time is usually a matter of supreme concern. In the working of mineral traffic, so long as deliveries are properly and systematically regulated, time is not of such great importance. This is the consideration that causes mineral traffic to be so much more largely carried on canals, and suggests to our traffic reformers whether much more might not be attempted in this direction.

The late Mr. Abernethy calculated that it would cost £12,000 per mile to put the canal-system of this country into a good serviceable condition, so as to be of any real use to the country, and capable of offering serious competition to railway transport, so far as they went. This would mean that nearly £46,000,000 would have to be expended on the existing system of 3,813 miles. It is more important to the coal trade than to any other interest to consider whether the game is worth the candle. The sum is large, but the railway companies have added nearly four times as much to their capital expenditure during the last ten years, so that there would seem to be no insuperable obstacle to the money being provided, if the end were to justify the means. An essential preliminary would, however, be that the most careful enquiries should be made as to the lowest cost at which canal transport could be effected under the altered conditions, with large boats, with electric and steam traction, with improved locks, and possibly also with a modified system of tolls.

From the figures, which had been supplied to him by the inventors, it would seem that the recently invented Thwaite-Cawley system of canal-haulage would be worth the careful consideration by those interested in economical canal transport. These figures—which it is stated are based upon data derived from actual practical working—show the cost of horse-power, per 12 hours day, for haulage purposes to be as follows :—

	s.	d.
Electrical haulage (Thwaite-Cawley system) ...	1	0
Steam-tug haulage	1	8½
Horse-haulage	3	11¼

The figures given for the steam-tug haulage are below the actual cost, as the damage to the canal banks from steam-boat traffic has not been

taken into account in the above relative estimate, and the cost due to such damage is, in some cases, very considerable. Farther, it has been assumed that the steam-tug always works at its maximum capacity. For light cargoes the steam-tug haulage cost would be increased.

If under the new conditions the canals could carry the great mineral traffic in anything like large bulk, at a rate not exceeding ¼d. per ton per mile, then the enterprize might be worth initiating.

One of the schemes that are at present *in nubibus* in this district is that of converting the Worcester and Birmingham navigation into a ship-canal, so that, as a continuance of the Severn scheme, steamships of 400 tons burthen would be able to pass from tidal water into Birmingham without break of bulk. The length of this navigation is 30 miles, and estimates have been furnished to carry out the work for £603,300, but whether the cost be less or more it would seem to be well worth trying. This measure, however, at the most would only relieve a comparatively small part of the coal industry of the country, and it would depend upon the extent of the traffic that could be put on the canals between Birmingham and the sea, whether it would relieve even that. One thing only is certain, namely, that the Birmingham and Midland traders generally are in great straits, in consequence of their relatively great distance from the sea. It is desirable to minimize as far as possible the inconveniences of the geographical situation of the Midland capital from this point of view. The railway companies either cannot or will not give additional assistance to this end. They are accustomed to charge from 10s. to 15s. per ton for transport of heavy traffic to London, while the cost of transport of like traffic from Liége to Antwerp, an approximately similar distance, is between 4s. and 5s. per ton, and from the Westphalian coal-field to Antwerp or Rotterdam very little more. In these circumstances, the Midland traders must work out their own salvation—not necessarily in a spirit of hostility to the railway companies, but in the spirit of the commercial principle which compels us to buy in the cheapest markets. England cannot afford to have it said that the manufactured goods in which this district so greatly excels can be delivered in Lancashire from Belgium and Germany more cheaply than they can be carried from Birmingham, which is only about one-third of the distance, and yet that is the anomalous position in which the staple trades of the Midlands are placed at the present time.

One of the most pertinent questions presented for solution in the consideration of this subject is that of the lowest cost at which traders can expect to have their traffic carried by water.

There are many facts available to guide us to a conclusion on this point. Take the experience of the United States as an example. Probably the most important movement of traffic in that country is that of wheat from Chicago to the sea-board. The railway rates have always been kept extremely low by the competition of the waterways between these two important distributing centres. There is no record of the all-rail rates up to the year 1868. Up to that date, the traffic was carried almost wholly by water, and the rates varied from a minimum of 16½ to a maximum of 29½ cents per bushel. The first average all-rail rate quoted was 42½ cents in 1868. Water competition brought the rate down to 24 cents in 1875, and to 14 cents in 1885. Meanwhile the water rate continued to drop cent by cent, until in 1892 it reached what almost appears to be an irreducible minimum at 5·61 cents. For the last ten years the all-water rate has been considerably less than one-half of the all-rail rate for the same service. The one system regulates and determines the charge on the other, and traders reap a great advantage thereby. The experience of the Aire and Calder navigation, with the most modern conditions of canal-transport, proves that heavy traffic can be carried on canals for an almost incredibly low figure. Mr. Bartholemew told the Select Committee on Canals in 1883, that the cost of transport on that system was only 0·03d. per ton-mile. It must not, however, be assumed that this is a typical figure. Canal rates have hitherto often been as high as those on English railways. On canals between Birmingham and London, under railway control, the average rate per ton per mile was stated to be 1·40d., but this was due to the railway administration. On the Grand Junction canal, which is an independent route, the average rate for the same service was only 0·35d.* and there is good reason to believe that this average rate might be still farther reduced if the conditions were made more favourable.

Mr, Lionel B. Wells (Manchester) read the following paper on "Canals":—

* *Report of the Select Committee on Canals*, 1883, page 253.

CANALS.

BY LIONEL B. WELLS, M. INST. C.E.

Canals, the generic term for all inland waterways in this country, is to the writer a very interesting subject, and one which has occupied much of his time during the last eighteen years. In 1877, he was appointed engineer to the River Weaver navigation, and found that extensive works were in progress for the improvement of that important waterway between the town of Northwich and the estuary of the Mersey. It became his duty to complete these, and to design and execute other works for the improvement of the upper portion of the river from Northwich to Winsford. The state of the navigation may be judged from a paragraph in Sir Charles Hartley's lecture on inland navigation, given at the Institution of Civil Engineers in 1885, in which he referred to the Weaver navigation as "the best study in England at present of modern canal appliances." The writer mentions this because he is addressing practical men, and he feels that whatever he writes would be more interesting if they learnt that he had practical experience in works of inland navigation.

The general question of "Canals" now under consideration is very difficult to deal with, owing to the lack of reliable information and statistics upon the subject.

The Blue Book published in 1890 giving returns for the year 1888 contains the latest and most detailed information available arranged for reference. The Board of Trade are quite aware of many of its defects. It is a serious matter to find the errors therein, quoted as a correct exposition of the facts relating to our canal-systems, not only in British but also in foreign publications, and although these figures have been published for four and a half years, they are still adopted by persons writing for the information of the public on the question. In the *Times* of May 16th, 1894, a long article headed "Our Canals" commences by stating how meagre was the information on the subject, it being confined to a map published in 1852 by the Government on the motion of Mr. Richard Cobden, the proceedings of Mr. Salt's committee in 1883, which, by-the-way, never completed its labours or made even an interim report, and the Report of the Society of Arts Conference in 1888; and then refers to the

Blue Book above mentioned, C—6,083, 1890, and adopts the figures contained therein. As a warning to those who may be inclined to rely too much on the information given in this Blue Book the writer will mention a few of the errors that he has noticed with respect to the canals of England and Wales.

The Blue Book states the total length to be 3,050 miles instead of 3,520 miles, made up of 2,026 miles of independent and 1,024 miles of railway-controlled canals, as against 2,256 miles of independent and 1,264 miles of canals controlled by railway companies; the important Gloucester and Berkeley ship-canal being one of those omitted.

The information to be gleaned from the returns of capital expenditure is equally delusive. The paid-up capital of the Wilts and Berks canal, 69 miles long, is entered as £19,441, whereas it probably cost £500,000; and the Weaver Navigation £265,000, which was the amount of the terminable annuities unpaid in 1888, and has since been reduced to £200,000. The return has been frequently used for the purpose of finding the cost per mile of the canals in this country. The writer does not suppose that it was intended to be applied to such a purpose, but there was no hint given that the total capital account ought not to be divided by the total mileage to arrive at the cost per mile.

As the writer could not find a satisfactory map of English waterways he has endeavoured to supply the want as well as circumstances permit, but he feels sure that there must be many omissions, and he should be very glad to receive information which would enable him to make it more accurate. The map (Plate XXV.) was prepared with the help of a friend (Mr. Swindells, M. Inst. C.E., F.R.G.S.) for the International Congress on Inland Navigation, held at Paris in 1892: no map of English waterways having been forthcoming at the previous congress held in Manchester, when excellent maps of the systems existing in foreign countries were exhibited. The original map is drawn to a scale of $\frac{1}{437,500}$ or 6·9 miles per inch. Plate XXV. is reproduced to one-fourth of the scale of the original map. The map shows all the existing inland waterways that the writer has been able to identify in full lines. The independent ones are indicated by blue lines, and the railway-controlled canals by red lines. The canals converted into railways, and those that are derelict or abandoned are shown by dotted lines.

A blight fell upon our canals soon after the advent of railways, and, unlike the French who seized the opportunity to acquire many of their canals for the State, our Government allowed one-third of the canal-mileage to be handed over to the railway companies. In the year 1846, 776 miles

of waterway passed by Act of Parliament under the control of railway companies, and at the present time, as already stated, 1,264 miles of navigation out of 3,520 miles are in their hands. In addition to this length, 140 miles have been converted into railways and 275 miles are derelict or abandoned. The mischief done does not cease there, for the railway-owned canals are frequently so situated that they break the line of through communication on the most important routes.

These points are made clearer by an examination of the map than by any written description. It shows how the through routes between London and Liverpool, London and Bristol, Birmingham and Liverpool, and Birmingham and the Humber are shorn of their independence. The company having the greatest mileage and the greatest pecuniary interest in inland navigation is the London and North-Western Railway Company, the greatest and most powerful rival to its prosperity. This company controls six canals having a total length of 460 miles. The Great Western Railway Company owns twelve canals, aggregating 260 miles; altogether forty-three waterways, having, as above stated, a length of 1,264 miles, are controlled by thirteen railway companies. There are upwards of one hundred and thirty different lengths of waterways and more than one hundred proprietors.

The waterways of England fall geographically into six groups. Five of these are connected with estuaries, viz., the Humber, Mersey, Wash, Thames, and Severn. The sixth centres round Birmingham; there are outlying canals along the coasts, but few of these are of any importance.

The canals connected with the Humber are all barge-canals, and among them is the Aire and Calder, the most successful of our inland navigations. The Humber group is connected with the Mersey by means of the Aire and Calder, and the Leeds and Liverpool; another route connects the two rivers by means of the Aire and Calder, Calder and Hebble, Rochdale, and Bridgewater canals. The Leeds and Liverpool and the Rochdale canals are now independent, but they were for many years under railway control, and the locks being of different sizes constituted a hindrance to the free exchange of traffic. There is a third line to Liverpool, by way of the Huddersfield, Ashton, Rochdale, and Bridgewater canals, but two of these are narrow-boat canals and owned by two railway companies.

Although there is less railway influence felt in this than in many other groups, the ill effects due to our want of a system in canal matters are very evident, especially along the shorter routes, viz., difference in size of locks, in depth of water, and four ownerships in a distance of 117 miles from tideway to tideway.

To the south, there is a connexion between the Humber and the Thames by way of the Trent and five other canals, one of which is narrow, and has hitherto been a block to through communication by barges. We shall see later that a step has been taken towards amalgamation on this route.

In mentioning the Mersey group, reference must be made to the Manchester ship-canal, but simply to remark that this is primarily for sea-going ships, and cannot properly be classed as an inland navigation. It is, however, used by barges, and although its tonnage and traffic receipts are not so great as its more ardent supporters prophesied, still there is a substantial use made of the canal, which is increasing every month, and the benefits conferred on Manchester and the neighbourhood in the shape of reduction of railway rates has already been very considerable. In alliance with the Manchester ship-canal is the Bridgewater, the most successful of our shallower barge-canals. In the Mersey group are also the Weaver, Trent and Mersey, and the Shropshire Union canals. The last two are railway-owned, and they form the only connexion with Birmingham and the south.

Around Birmingham, the canals are all narrow, and to a great extent owned by railway companies. There is, however, an independent route to the Severn, and although hitherto there has not been a heavy traffic carried along it, it has been useful in keeping railway rates in check, the rates from Bristol and South Wales being lower in proportion to the distance than the rates from Liverpool, while the Gloucester and Berkeley canal has materially added to the prosperity of Gloucester and the Midlands.

From the Severn to the Thames the present condition of inland navigation is deplorable. There are two distinct routes, one by the Stroudwater, Thames and Severn, and river Thames, and the other by the river Avon, Kennet and Avon canal, and rivers Kennet and Thames. The Great Western Railway Company own a portion of each route. The one by way of the Thames and Severn canal is practically closed, while the Kennet and Avon canal has become shallow for want of dredging, and the use of steam is prohibited on it, the Board of Trade supporting the railway company in maintaining this prohibition. These canals are both barge-canals.

There is a narrow canal, the Wilts and Berks, between the two, but this joins the railway-owned Kennet and Avon, and is much in need of repair. A movement is on foot for taking the Thames and Severn canal out of the hands of the railway company and vesting it in the neighbouring navigations.

From the Thames, that is to say London, to the north-west or Mersey and north-east or Humber groups, the only practicable route is by way of the Grand Junction canal, one of the five already mentioned as forming a connexion between the Thames and the Humber. This is a barge-canal, in good working order and able to pay a fair dividend, although it follows the course of the London and North-Western railway and hitherto has had no northern terminus of any value. It communicates with Birmingham by means of the Oxford, Warwick and Napton, Warwick and Birmingham, and Birmingham and Warwick Junction, all narrow canals, and to the north over the Grand Union, and the Leicestershire and Northamptonshire Union to Leicester, thence by way of the Leicester navigation, and Loughborough canal, to a junction with the Trent.

The group connected with the Wash are all river navigations, but being in a country where drainage is of the first importance, navigation interests have not held a high claim to consideration. There are water connexions with the Grand Junction canal by means of a narrow canal branch from Northampton, and with the Trent by means of the Witham and Foss-dyke navigations, both of which are owned by railway companies. The condition of the Ouse from St. Neots to Earith was investigated by Major Marindin, an inspector from the Board of Trade in 1890, and its condition was reported to be deplorable. The locks had fallen into decay, not only the timber-work but also the brick-work and masonry, while the drainage of the valley was impeded by weirs and other obstructions. It was found that no less than seven public bodies were concerned in the river, and had power to obstruct any alterations.

In connexion with the Ouse and its navigable tributaries there are at least nine toll-taking bodies. It can be readily understood that under these conditions navigation is at the lowest ebb. Indeed the collapse has been so thorough that sufficient energy was not left to enable several of the commissioners to make the return required at their hands in 1888. The writer does not hear, however, that they have ceased to take toll from any trader who tries to pass their way. Since 1888, there has been a revival of interest in navigation in Fen-land, and money is being spent in improvements on the Ouse, while the Lark has been again restored as a navigation for lightly-laden barges.

Having regard to their dimensions the canals of England and Wales may be divided into five classes.

	Miles.
(1) Narrow boat-canals, aggregating about	1,240
(2) Shallow barge-canals	2,040
(3) Improved barge-canals, 6½ feet deep and upwards	230
(4) Ship-canals, 13 feet to 18 feet deep	23
(5) Manchester ship-canal	35½
Total	3,568½

(1) The dimensions of the locks of the narrow canals in England vary, and provide for boats differing in length from 71 feet to 81 feet, with beam varying from 6 feet 4 inches to 7 feet 2 inches. The depth of water also varies. The cargoes may be placed at from 18 to 30 tons.

(2) The small barge-canal locks accommodate vessels differing still more in dimensions, and the barges carry cargoes varying from 40 to 60 tons.

(3) The improved barge-canals accommodate craft carrying from 90 up to 350 tons; this weight has been taken in one cargo on the Weaver, and the locks will accommodate a train loaded with 1,000 tons.

(4) Ship-canals are short and of no present importance, except the Gloucester and Berkeley, which has a large traffic.

(5) Manchester ship-canal.

Although no statistics exist, so far as known to the writer, of the tonnage carried on canals in former days, he thinks we may be very sure that it is the one description of traffic that has stagnated in most, and retrograded in many instances in this country. There are a few prosperous companies in different parts of the kingdom, proving that it only requires skill, enterprise, and commercial ability to make this means of conveyance a success in many other localities. The tonnage of shipping entering our ports per head of population is threefold what it was forty years ago, and during that time the population has nearly doubled in number, therefore to supply our wants six times as much transport is required as in 1850. These figures help us in some degree to realize the enormous additions made year by year to the movement of traffic throughout the land. This conveyance has become a necessity for our food-supply and our trade generally, and as the country increases in population and wealth it must continue to grow. The point we have to consider is whether we can move this enormous traffic more economically than at present, and so aid in the general prosperity of the nation. In the commercial world there is no question of greater importance than the cost of transit. Other things being equal, the nation possessing the cheapest means of conveyance must gain the day in the struggle for industrial supremacy.

It is noteworthy that the great advance made by England in manufactures towards the latter part of the last century coincided with the development of canals and river-navigations. In discussing the matter with an American engineer at the last International Congress, he went so far as to say that it was James Brindley who really conquered the Emperor Napoleon. It was largely, he averred, due to the cheapening of transport by Brindley's canals that England prospered as a manufacturing country, became wealthy and able to provide the sinews of war, not only for arming and equipping her own soldiers and sailors, but for subsidizing European nations to fight against the common enemy. Without going so far as this, the writer agrees that our debt to Brindley for assisting our manufacturers and increasing our wealth is very great, and we cannot acknowledge it more suitably than by resuscitating the traffic that has been lost and adding to the amount of traffic on inland waterways for the benefit of our generation and those who come after us.

Grant, for the sake of argument, that we are acting wisely in neglecting canals, at any rate other nations do not continue to practice that policy. On the continent of Europe, as well as in Canada and in the United States of America, great attention is now paid to the question, in spite of the fact that their railway rates are far cheaper than ours.

A correspondent of the *Manchester Guardian*, who has devoted much time in collecting statistics on the movement of traffic within the United Kingdom by rail and water, considers that the weight annually transported is approximately as follows :—

	Tons.
By railways	309,596,000
By canals and navigable rivers	36,300,000
Or for internal transport	345,896,000
Shipped coastwise	25,000,000
Total for home transportation ...	370,896,000

This figure represents about 9 tons per head of population ; but as both on railways and canals the same goods (carried on more than one system) are recorded over again, under the present mode of making returns no means of obtaining accurate information is provided.

The above tonnage compares with 84,000,000 tons of cargo moved in ships trading to the Colonies and to foreign ports.

These figures indicate the enormous quantity of goods moved internally, and point to the paramount importance of our obtaining the best and cheapest means of conveyance, for the aggregate movement of this traffic is 345,896,000 tons per annum. Coastwise and over-sea traffic together

reaches 109,000,000 tons, showing that the weight transported by railway and canal is more than three times the united volume of our boasted sea-going and coasting trade, of which we are greatly proud, and to defend which we are ever ready to spend our lives and fortunes.

In an article recently published in the *Contemporary Review** on the "Carrying Trade of the World," Mr. Mulhall gives a number of interesting figures and statistics on the subject. He states that in the last twenty-two years the carrying power by sea has doubled, and traces a relation between the increase of shipping and of railway traffic. He states that the carrying power of the world has increased threefold since 1860, and that the ordinary cost of land-carriage for goods in Europe in 1850 was 8d., whereas now it is under 1d. per ton per mile.

In the last century, the cost of carriage by land to towns in the valley of the Thames to and from London was between 7d. and 8d. per ton per mile. This was reduced to one-half by the use of the imperfect and shallow waterways then provided. These figures confirm the previous statement, that the rates for carriage in this country were much lower than those on the Continent at the close of the last century.

The *Journal des Economistes* states that the ordinary freight charge per ton per mile on railways is as follows:—United States of America, 0·40d.; Holland, 0·78d.; Belgium, 0·80d.; Germany, 0·82d.; France, 1·10d.; Russia, 1·20d.; Italy, 1·25d.; Great Britain, 1·40d.; and the average, 0·97d. per ton per mile.

Assuming that the writer has made an accurate comparison, and that approximately the same services are rendered for the charges quoted, this statement shows that the rates on our railways are 350 per cent. higher than those of the United States and 75 per cent. higher than those of Belgium, a neighbouring manufacturing country.

The average returns of net receipts on railways are given for fourteen countries, from which the writer selects the following:—India, 5·2d.; Germany, 5·1d.; Belgium, 4·6d.; United Kingdom and Egypt, 4·1d.; France, 3·8d.; and the world, 3·2d.

It is noticeable that our net railway receipts are among the highest, and seeing that the volume of traffic is so much greater than in any other country, the income ought to be proportionately large, but unfortunately the want of system in laying out the lines, the great cost of land and preliminary expenses, and the large sums spent in railway construction have so swelled the capital accounts that one looks in vain for any considerable cheapening of the cost of transportation from the railway companies.

* 1894, vol. lxvi., page 811.

Railway companies do not compete in rates. They are agreed, and the competition commences with a struggle to obtain traffic at the "agreed rate." Many trains are run, which would be unnecessary with due regulation, and large sums of money are spent in canvassing for traffic. The cost of all this has to be covered by the charge for carriage. The only real competition with railways is exercised by independent waterways, on which the public can carry their own commodities. It is impossible to do this on railways, and consequently various kinds of arrangements for making the public pay too much are feasible.

In 1870, the average cost of railways in the United Kingdom was £34,000 per mile, and this is the lowest amount returned. Since then it has increased year by year, until in 1893, it reached £47,000 per mile, and the contracts for the extension of the Manchester, Sheffield, and Lincolnshire railway from Nottingham to Quainton Road, to give access to London, show that this will cost at least £65,000 per mile for construction alone.

The cost per mile of making railways throughout the world varies but little from year to year—

	Per Mile. £
In 1840 it averaged	15,800
„ 1860 „	16,300
„ 1880 „	17,200
„ 1892 „	15,500

The latest return being the lowest, whilst in our country it stands at 38 per cent. above the lowest.

We as a nation were the first to supplement our advantages in cheap transport coastwise by constructing inland waterways, and we were also the first to utilize railways extensively. By these methods we undoubtedly gained a great advantage for our merchants and manufacturers, and added to the prosperity of the nation in times gone by. Now, however, we labour under the disadvantage of having to pay far higher rates for the carriage of our internal traffic than any of our competitors for the trade of the world. It therefore behoves us to see what can be done to alter a condition of things which bodes ill for our continued prosperity.

As we have seen the cheapest railway carriage is provided in the United States of America, where the average rate is 0·40d. per ton per mile, but in the same country the cost of carriage by water is said to be 0·20d., or one-half the cost of carriage by railway. The Americans are not content with this, but are annually spending large sums to improve their canals and rivers. To mention the most important of many in hand and in contemplation, a canal 36 miles long is being made through

Chicago, which will connect the waters of Lake Michigan with the river Missouri. Its primary object is for drainage purposes, but it is 160 feet and upwards in width, and will be made ultimately 22 feet deep. This canal will allow of the passage of vessels from the Great Lakes and their tributaries, some 15,000 miles in extent, to the waterways connected with the river Mississippi and its tributaries, 16,000 miles in length, and form a vast system of internal water-transit such as the world has never seen before. All these waterways will be toll-free. The Americans are, the writer believes, our most formidable rivals in the future for the trade of the world, and they inherit much of our energy and capacity for business. They raised in 1893, 162,800,000 tons of coal, as compared with 164,300,000 tons raised in the United Kingdom in the same year, which was, however, the year of the great coal strike. The coal output in the United States of America in 1889 was 126,000,000 tons, showing an increase of 36,800,000 tons, or 29 per cent. in four years.

The largest coal output returned for this country was in 1892, viz., 181,800,000 tons, and showed an increase in four years of only 7 per cent. The Americans claim that with a population of 65,000,000 the United States of America produce and consume over one-third of the iron, cotton, and copper, and consume one-fourth of the wool and sugar produced throughout the world.

If it were not that the distances which separate the products of the country are so great, the writer would fear for our position. We have at any rate no points to lose, and unless we make use of our inland navigations as a supplement to our coasting and over-sea trade we shall be neglecting a golden opportunity.

Railway rates have been decreasing in the United States of America for a number of years. In the case of seven trunk lines, including the New York Central, the Erie, etc., railways, the average freight rate per ton-mile fell from 1·4d. in 1865 to 0·32d. per ton in 1890, whilst the average net incomes increased on these trunk roads from 4·04 per cent. in 1865 to 6·39 per cent. in 1890. In spite of the reductions above-mentioned, the average value of the stocks of these seven great railway companies was virtually the same at the two periods. These roads are parallel to or in continuation of the line of navigations through the Great Lakes, and were competing with the most commodious water-route in the country. The great reductions in rates were usually commenced on these railways and spread to other parts of the United States of America. In fact, industries flourished, and rendered low freights beneficial to carrier as well as to producer and consumer.

The impossibility of regulating railway rates by law has lately been proved in America, where the Inter-State Commission appointed for this purpose has failed. In this country we have had little or no reductions in transport charges by railways, during the last forty years, and after ten years of agitation and an enormous expenditure of time and money, it is questionable whether even now any appreciable reduction has been obtained. These charges, it should be remembered, were first levied when the value of money was relatively much higher than it is now.

The following is an extract from an address on the subject of "Freight Rates" by Mr. E. R. Johnson, Instructor in Political and Social Science, Haverford College:—

The cheapest freight rates by rail to be found in the world are those for grain between Chicago and New York. And why? Because the cheapest inland water-transportation rates in the world are those between the same points.

All the railroads of the United States have been steadily lowering freight charges during the past twenty years, and largely, of course, because improvements in track and equipment have made this possible. Those roads, however, that have made the most improvements and the greatest reductions in rates are the great trunk-lines leading into New York from the west—those that compete with the Great Lakes, the Erie canal and the Hudson river. The average freight earnings per ton-mile of all the railroads of the United States for the year ending June 30th, 1890, were 0·941 cent. For the year ending June 30th, 1891, they were 0·895 cent. The ton-mile earnings of the New York Central and Hudson River railroad were 0·730 cent, and on the Pennsylvania railroad 0·661 cent; on the Lake Shore and Michigan Southern 0·653 cent; and on the Michigan Central 0·726 cent; whereas the average earnings per ton-mile on the Chicago, Milwaukee, and St. Paul, and on the Chicago and North-western roads coming but slightly into competition with the Great Lakes and other waterways were 1·06 and 1·03 cents respectively. The following table, showing the wheat rates per bushel from Chicago to New York for the years 1868, 1880, and 1891, by water, by water and rail combined, and by rail, indicates very plainly how freight rates have fallen, and how this movement has been led by the waterways:—

	By Lake and Canal. Cents.	By Lake and Rail. Cents.	By Rail. Cents.
1868	22·79	29·0	42·6
1870*	17·10	22·0	33·3
1880	12·27	15·7	19·9
1889*	6·89	8·7	15·0
1891	5·96	8·53	15·0

The important influence of the Erie Canal on freight rates has often been emphasized.

In Belgium, railways are owned by the State, and the tolls are fixed so as to provide the cost of working, maintenance, and bare interest on the capital cost; so little margin, indeed, is allowed that some years ago the passenger fares had to be raised to prevent the State from being an absolute loser. The lowest remunerative charge for working is stated by the Minister of Public Works to be 0·483d. per ton per mile.

* The figures for 1870 and 1889 are in addition to those given by Mr. Johnson.

In France, the charge under very similar conditions is put at 0·592d. per ton per mile, and is made up as follows:—

Locomotive power	0·140d. per ton per mile.
Rolling stock	0·078d. " "
Wages and maintenance	0·078d. " "
Interest and general charges	0·296d. " "

Sir Geo. Findlay, the late general manager of the London and North-Western Railway Company, stated that the cost of working full train-loads of coal and returning empties between Wigan and London was 0·21d. in 1870, and had risen to 0·24d. per ton per mile in 1875.

These results, together with the charge of 0·4d. per ton per mile already quoted as the cost by American railways, appear to give good ground for taking 0·5d. or ½d. per ton per mile, as the lowest possible rate of carriage for general goods traffic by railway in this country, if a moderate return is to be paid to the shareholders. The freight-rate for coal on the Taff Vale railway in owners' trucks for a full train-load and for one consignee was given as 0·55d. per ton-mile in 1889, the statutory charge for waggon hire being 0·125d. per ton-mile.

Mr. Gobert, who has studied this subject, puts the cost by canal on annual traffic of 600,000 tons per mile in Belgium as 0·284d. per ton per mile made up as follows:—

		D.
Tolls	Interest and redemption of capital	0·112
	Repairs and maintenance	0·022
Freight	Towing by steam	0·047
	Boat and boatmen	0·103
		0·284

This is a trifle above the cost of the through coal trains, for working only, as given by Sir George Findlay.

The 4 per cent. is taken on a capital cost of £11,500 per mile. Mr. Dufourny states that the rate of freight from Liége to Antwerp is from 1s. 9½d. to 1s. 11d. per ton on a navigation 97 miles long and 7 feet deep, or less than 0·25d. per ton per mile, and that in spite of two competing lines of railway, the traffic amounts to 570,000 tons per annum.

Upwards of 6,000,000 tons of goods are carried into Paris by water annually. This traffic is 41 per cent. of the total entering the city by railway and water; 1,000,000 tons is carried from Rouen in direct competition with a railway.

Berlin is supplied to the extent of one-half of its imports by canal.

Of late years the percentage carried by water has increased in much greater proportion than by railway in both France and Germany.

Of the traffic carried by rail and water in the United States, 27½ per cent. is water-borne, notwithstanding the cheap railway rates that rule in that country; in France it is 30 per cent.; and in Germany 23 per cent.; whereas in the United Kingdom it is less than 11 per cent., and this value is too high owing to the goods being returned over and over again by different canal companies.

If our competitors are economically right, we must be economically wrong in not using inland waterways to a much greater extent for the purpose of transport.

The capacity of canals for traffic may be partly gauged by taking the figures in the return for 1888 wherein we find that with a length of 159 miles the Birmingham canals are credited with a traffic of 7,713,000 tons, or 48,500 tons per mile, but as portions of the system are congested with traffic while other portions are much less used, it is clear that on certain lengths the tonnage bears no comparison to this amount. On the Birmingham and Warwick Junction, a canal for narrow boats only 2 miles 5 furlongs long, having six single locks, the return shows the traffic for the year to be 194,680 tons or 77,900 tons per mile.

The Weaver navigation return gives 1,500,000 tons on 20 miles of waterway, or 75,000 tons per mile. Nearly 1,000,000 tons of this traversed practically the whole system, and over the lowest portion the ton-mileage must have been at least 1,300,000 tons per mile. The lower portion of the Aire and Calder navigation carried a still greater ton-mileage over a single-lock system, and the Bridgewater, a barge-canal, passes 1,300,000 tons over a portion of its length.

On the Aire and Calder navigation, coal is conveyed in floating-tanks made up in long trains and hauled by a tug. The cost, including returned empties, was given before the Committee on Canals in 1883 as 0·0087d. per ton per mile, the journey loaded costing 0·0084d. This system has been continued, the plant for dealing with coal doubled, and the shipment of coal from Goole has increased enormously of late years. It was farther shown that on a movement of 4,000,000 tons of merchandize by cargo-carrying tugs, the cost was 0·03d. per ton per mile. Horse-haulage on the same route cost 0·14d. per ton per mile, nearly five times as much, and that, on the smaller section of the Leeds and Liverpool canal, on which boats are taken from the Aire and Calder, horse-haulage cost 0·33d. per ton per mile, ten times as much as steam-haulage, and more than double as much as horse-haulage on the larger canal.

The Weaver navigation has a larger sectional area than the Aire and Calder, and the haulage by hired horse cost 0·05d. for the double-journey

(laden down and light up the river), as compared with 0·14d. per ton per mile on the Aire and Calder. Horses have to a large extent given place to steam on the Weaver, no doubt for reasons of economy as well as for speed and regularity of service.

If we regard the question of haulage in comparison with that of tolls charged, in fierce competition with railways, we see the preponderating importance of haulage.

The through rate of toll for bricks from the Midlands to London has been agreed at 2s. 6d. per ton, including 14 miles on the Birmingham canal. It is 135 miles from Birmingham to Brentford on the Thames, making a distance by canal of 149 miles.

	£	s.	d.
Taking 24 tons as a boat-load, the toll on 24 tons at 2s. 6d. amounts to	3	0	0
Haulage and navigation cost 0·33d. per ton per mile for 149 miles	4	19	4
Total cost of horse-haulage	£7	19	4

If the haulage be taken at the rate of steam-haulage ruling on the Aire and Calder twelve years ago, the account would stand as follows:—

	£	s.	d.
Toll	3	0	0
Haulage-cost, 0·03d. per ton per mile for 149 miles ...	0	8	9
Total cost of steam-haulage	£3	8	9

A difference of £4 10s. 7d. per trip. From this amount must be deducted the wages paid to the boatmen (the rate per ton varying with the capacity of the vessel), and the net saving would allow for an increase in toll, and leave a handsome profit under present conditions, but seeing that the cargo would be carried over five canals, if these were amalgamated a still better result would be obtained. A toll of 2s. 6d. per ton for 149 miles is at the rate of 0·201d. per ton per mile. Of this sum, the Birmingham canal claims 4d. as a minimum, 50 per cent. more than its fair mileage-proportion for 14 miles, beyond which distance an increase of toll is levied, while the Oxford canal takes 3d., or three times its due mileage-proportion, notwithstanding the fact that there is no lock on this length of the canal. It is singular, that the ordinary powers given by Parliament in the Acts of last year, viz., 0·5d. per ton for the first 10 miles, 0·45d. per ton for the next 10 miles, 0·25d. for the third 10 miles, and 0·15d. for the remaining distance owned by one canal company, would, if the 149 miles were in one canal work out to 0·201d. per ton per mile. The Oxford is an independent canal company, paying a dividend of 7 per cent. We have been accustomed to hear of the hard

measure dealt out to canal traffic on railway-owned canals, but we have here an example of an independent company levying an exorbitant proportion, viz., $\frac{1}{10}$th of the toll for $\frac{1}{30}$th of the mileage. The above figures deal with tolls and the haulage of a loaded boat, apart from handling, terminals, cost of boat, and other charges.

Since 1882, economies have been effected in the use of steam, and it is necessary that many of our waterways should be improved so as to render its use more advantageous to the carrier. Canals with few exceptions, remain what they were before the introduction of the locomotive and are still worked by horses. The locomotives first used on the Liverpool and Manchester railway weighed about 4 tons and ran on iron rails weighing 35 lbs. per yard, drawing light trains. Now we have locomotives of 50 tons, steel rails of 90 lbs. per yard, and locomotive and train weigh upwards of 400 tons. In America, locomotives of 70 tons are now in use.

It is only necessary to compare the efforts made (with such signal success) to develop the carrying capacity of railways, with the neglect accorded to canal traffic, to see one great reason for the advance of the railway and the decay of the canal.

The advantage of large canals is shown by reference to the size of boats lately built in France. Between 1887 and 1891, the number of barges 126 feet long, suitable for passing the locks of canals of the first class, increased from 933 to 2,016, or 216 per cent. At the latter period 7,500 barges were capable of carrying 200 tons and upwards, and this number was nearly one-half of the craft employed on internal waterways.

The best design for barges of all sorts, and the best material of which to construct them, is a question well worthy of consideration, and if some gentlemen present would favour the meeting with an account of their experience, the information would be most serviceable, for we have no authoritative guide to refer to, and every owner is left to follow his own fancy.

Nearly all craft using canals are built of wood, but by degrees metal is being employed. Narrow canal-boats are confined to inland waterways almost entirely; they, however, navigate the estuary of the Thames as low as the London docks; they do not venture on the wider and more stormy estuary of the Mersey. The barges using the second and third class canals navigate estuaries, and in many cases are provided with masts and sails, enabling them to proceed coastwise, the larger ones often conveying cargo for a considerable distance. Steamers which can be accommodated on the Weaver and Severn now ply regularly between London and Paris, as well as towns situated on canals in Belgium.

Messrs. W. Cory & Son, of London, coal merchants on a large scale, made an experiment last autumn in building eight sea-going barges. They are of steel, 125 feet long, 21 feet beam, draught loaded 8 feet. When light they stand 13 feet 6 inches above the water. Each barge carries 350 tons of coal. They are battened down and towed by steamer. Since last September, coal has been carried in these barges from the east coast, more especially the Humber-ports, to London; and when certain alterations about to be made to bridges on the Aire and Calder are completed, the barges can be loaded at the stages belonging to six of the West Yorkshire collieries, and thus the damage done to the coal by transhipment will be avoided, as well as the expense attending that operation. During one of the most severe of the recent gales, six of these craft were at sea and safely weathered the storm. The owners, moreover, are quite satisfied with the result of their experiment after four months' trial at the worst season of the year, and if coal can be carried in this manner, similar barges will, no doubt, be used for the carriage of other commodities, and the creation of this traffic adds another to the many reasons for improving canals.

From experiments recently made in France, it would appear that much greater importance attaches to the build of boats and the material of which they are constructed than is generally supposed. It is stated that a large reduction in resistance was gained when the sides of a wooden barge were covered with oilcloth. The barge was, the writer understands, towed at a speed of only $2\frac{1}{4}$ miles per hour. The spoon-shaped bow is also said to offer the least resistance to the passage of the boat through the water, while diminishing the carrying capacity of the boat to a smaller extent than a sharp bow.

If we refer to the Returns to the Board of Trade, 1890, we see that the Aire and Calder and the Weaver navigations, which, by improvement have been kept abreast of the age and are together only 113 miles long, carry 3,750,000 tons per annum, out of a total of 34,325,000 tons transported on our canals, or approximately $\frac{1}{9}$th of the total tonnage is carried on $\frac{1}{27}$th of the total length. On the other hand, independent canal companies are credited with a length of 2,025 miles, and a tonnage of 27,715,000 tons, or 13,700 tons per mile, while railway-owned canals with a length of 1,024 miles, carry 6,609,000 tons, or 6,500 tons per mile, less than half the tonnage per mile carried on the independent canals. These figures point to the necessity of freeing canals from railway control, and afford an example of the amount of traffic that can be worked on efficient waterways in keen competition with railways.

Abroad, the tendency is for long-distance traffic to be taken by water rather than by rail, which is, apparently, the reverse of what obtains in this country. Minerals and heavy goods provide the bulk of the traffic by water abroad; but on many of our smaller canals, at any rate, this is not the case. The coal traffic by water to London is a bagatelle compared with the traffic by rail, whereas the coal and fuel brought from Belgium and the north-east of France to Paris is the heaviest traffic on the canals of that country, and over a portion of the river Seine below Paris amounts to upwards of 1,500,000 tons per annum.

The larger the cargo the greater is the economy in transit, as proved by the increasing size of modern ships and the demand for deep-water docks and harbours. Especially is this true of cargoes carried by canal where two boatmen can manage a barge of 300 tons, when an efficient waterway, that is one with ample sectional area, is provided. The saving in traction is also very great indeed. When steam-tugs were introduced on the Bridgewater canal, three laden barges were towed in train, but as the sectional area of the canal was improved, a fourth was added, and for many years the usual train has been four barges, each carrying a heavier cargo than at first.

The ordinary load for one horse is one barge carrying 60 tons, or two narrow canal-boats carrying 50 tons. The hauling of more than two is discouraged, owing to the length of time occupied in passing the numerous bridges. On a narrow canal, each boat would require a horse.

On the Weaver navigation, a single horse hauls a cargo of 100 tons, and 250 to 300 tons only requires two horses. The large barges on the Continent, carrying 300 tons of cargo, are hauled by two horses. The economy does not stop with this saving in haulage, as the narrow canal-boat costs upwards of £6 per ton of cargo to build, and a Weaver barge, carrying 260 tons, only costs about £4 per ton.

Economy of transport by water is assisted by the lessened cost of plant. A railway-train loaded with 220 tons costs for the locomotive and trucks £3,360. A steam-barge to carry the same quantity will cost £1,600; but this barge can be and is frequently employed to tow three other barges of 260 tons capacity, costing £1,000 each, and this not merely in the still waters of the Weaver and the Manchester ship canal, but across the estuary to Liverpool.

We thus find 1,000 tons carried by one steamer of 220 tons, costing £1,600, and three barges, of 260 tons (£1,000 each), costing £3,000, or £4,600 in all; whereas the cost of the railway-plant, for the same tonnage, would amount to £15,000.

The primary necessity is to free canals from railway control, and promote amalgamation of the various companies. Parliament recognized this view when it adopted the report of the Joint Committee of the two houses appointed in 1872, who stated *inter alia*:—

The most important method by which the railways have defeated the competition of canals has been the purchase of important links in the system of navigation and the discouragement of through traffic.

That no inland navigation now in the hands of a public trust shall be transferred to or placed under the control of a railway company, and that if the trustees of an inland navigation or of a canal apply to Parliament for power to purchase compulsorily a canal from a railway company, such purchase shall be favourably regarded by Parliament.

That the utmost facilities shall be given for the amalgamation of adjoining canals with one another or with adjoining inland navigations.

That no canal shall be transferred to or placed directly or indirectly under the control of any railway company, nor shall any temporary lease of any canal to a railway company be renewed, until it has been conclusively ascertained that the canal cannot be amalgamated with or worked by adjacent canals, or by a trust owning an adjacent inland navigation.

The amalgamation of existing canal companies is very necessary. The London and North-Western Railway Company is made up of forty to fifty different companies, and extends its connexions to Scotland and across the sea to Ireland. The two canal companies having the greatest mileage at the date of the Board of Trade return were the Shropshire Union, with 200 miles, and the Birmingham, with 159 miles, both of which are controlled by the London and North-Western Railway Company. Next in length was the Grand Junction, an independent canal company, with an aggregate length of 140½ miles. This company has lately purchased the Grand Union and the Leicestershire and Northamptonshire Union canals, and increased its length by 48½ miles, making a total of 189 miles under one management. The canal commences at Brentford on the river Thames, and is connected by a branch to Paddington with the Regents canal. Hitherto it has terminated by junctions with other navigations without reaching a large town. Now, however, it extends northward to Leicester, and will, let us hope, continue its policy of amalgamation until it joins hands with the Trent navigation at Nottingham, and in a westerly direction acquires the canals intervening between Braunston and Birmingham.

From the river Thames to Birmingham is 135 miles. Of this length 93 miles is Grand Junction proper, having barge-locks. The remaining 42 miles is over three companies' canals, 5 miles owned by the Oxford Canal Company, 14½ miles by the Warwick and Napton, and the remaining 22½ miles by the Warwick and Birmingham Canal

Company. These three canals are unfortunately narrow, and limit the through cargo between London and Birmingham to about 24 tons.

These facts lead up to the question of the necessity for improving canals. The utter disregard for uniformity in dimensions has been a great hindrance to their usefulness and prosperity. Uniformity of gauge was soon found to be necessary for railways, and has been achieved in spite of the great expense entailed in making the change. The canals, with few exceptions, remain as they were first made, differing in length and width of locks and in depth and width of waterway.

In France, a law was passed in 1879 enacting that all canals of the first class should be made for craft carrying 300 tons. This law requires the locks to be 131 feet long, 17 feet wide, 6½ feet deep over the sills, and that all over-bridges should have a headway of 12 feet. At that time there were 912 miles of canals and navigations which came up to the required standard out of a total of 7,300 miles. In 1892 there were 2,509 miles. This increase was attained by the addition of 390 miles of new and the improvement of 1,207 miles of old canals. The result has been that, whereas in 1876 the traffic amounted to 1,221,000,000 tons per mile, in 1891 it had increased to 2,211,000,000 tons per mile, an addition of 81 per cent. over the whole of France, but if the comparison be confined to the improved canals the addition amounts to 109 per cent. The increase in the average length of journey between 1881 and 1892 has been from 69 miles in 1881 to 192 miles in 1892, and the number of boats of the new type increased 54 per cent. between 1887 and 1891. The length of canal or navigation carrying the heaviest traffic connects the coal-fields of the North of France and Belgium with Paris. The length from the frontier is 177 miles. The tonnage carried on this line of canals in 1875, amounted to 283,875,000 tons per mile; in 1885, it amounted to 364,237,000 tons per mile; in 1891, it amounted to 453,197,000 tons per mile, an addition of 60 per cent. in sixteen years. In 1891, more than 21,000 boats passed through certain locks on the line of canals, having a total carrying-capacity of over 3,500,000 tons. Since 1881, considerable improvements have been carried out on these canals, enabling the cost of traction to be reduced, and with it the freight charges have been lowered by 15 to 20 per cent.

The canals of the first class which, as we have seen, are about 2,500 miles in length, are approximately one-third of the total length of the inland waterways, carry two-thirds of the tonnage shipped on the canals, and the work done on them amounts to four-fifths of the total ton-mileage traversing the French waterways. These figures show the immense superiority of an efficient canal. The traffic is seventeen times more

active on the main lines of communication than on the secondary routes. In 1876, the ton-mileage carried on French canals amounted as we have seen to 1,221,000,000; in 1884, to 1,532,000,000, or an addition of 25 per cent. in eight years. In 1893, it was 2,256,000,000 tons per mile, an addition of 47 per cent. in nine years following; while in twenty years the traffic had doubled.

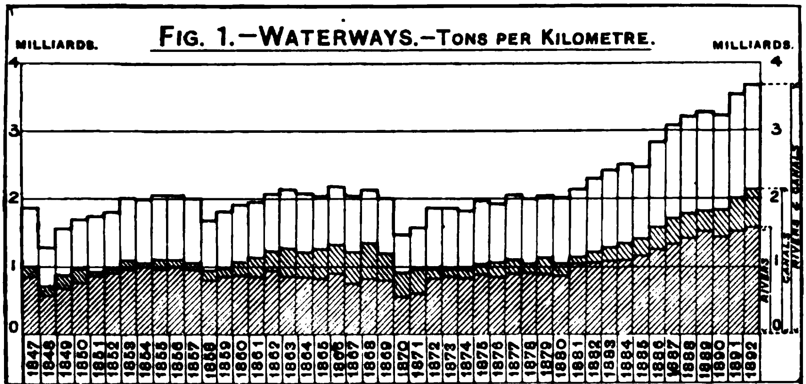
It is also found that the mean length of voyage is 91 miles by canal and 82 miles by railway, and that the St. Quentin canal over a portion of its length carries 4,456,000 tons, whereas the most heavily-worked railway line, which is between Avignon and Marseilles, carries only 2,787,000 tons per annum.

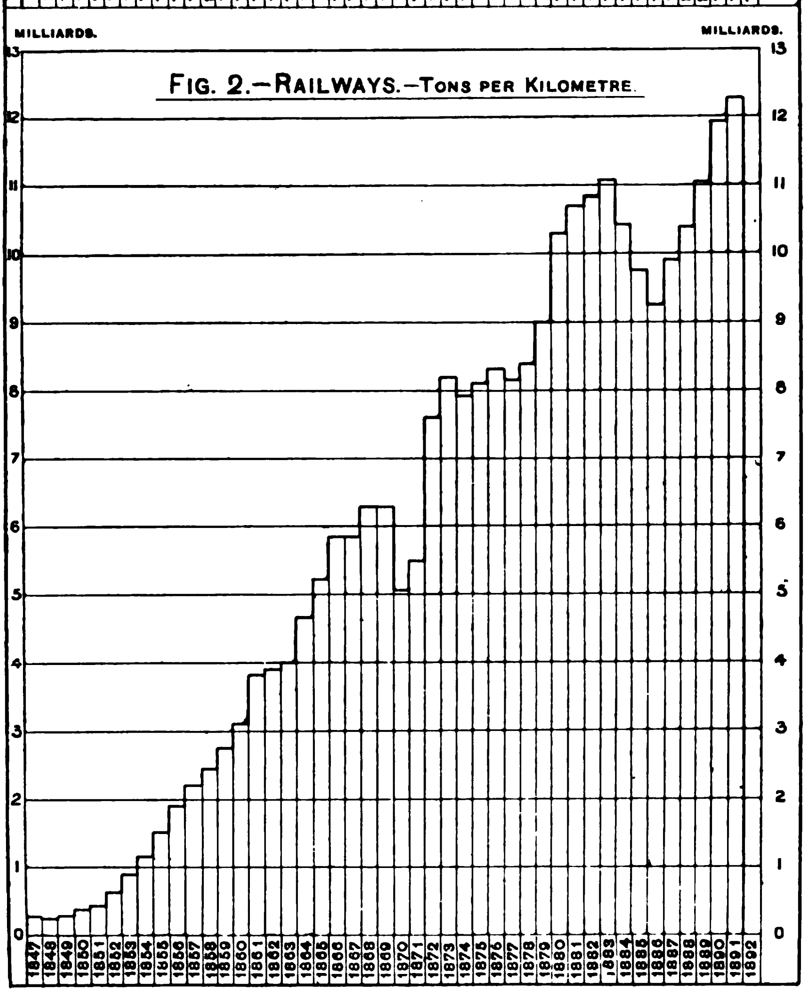
The growth of canal-traffic as compared with railway traffic is also worthy of consideration, for the tonnage per mile carried, divided by the total length of the two systems, shows that the use of canals per mile is now 84 per cent. of the user of the railways, whereas in 1882 it was only 41 per cent.

Figs. 1 and 2 show in tons per kilometre (a kilometre being approximately $\frac{5}{8}$ mile) the quantity of goods and minerals moved during each year from 1847 to 1891 by water and rail. It will be seen that starting from a few thousands of tons in 1847, the French railway tonnage had overtaken the canal tonnage in tén years, and has increased very materially since then, but from about 1880 the comparative increase has been at a diminishing ratio.

In 1882, the total length of railway lines in France was 16,044 miles, and of canals 7,644 miles. The total weight per mile carried on the railways amounted to 6,865,500 tons and on canals to 1,415,000 tons, or 20 per cent.; in 1892, the length of railway lines was 21,800 miles, an increase of 5,755 miles; whereas the length of canals was 7,747 miles, an increase of only 122 miles. During this period the railway-carriage increased to 7,575,000 ton-miles, the canal-carriage to 2,255,625 ton-miles—that is, the canals did 30 per cent. of the carrying work in the latter period as against 20 per cent., in the former, although their length had remained practically unaltered.

Having passed in review some of the principal circumstances attending the use and development of canals, and having noticed the neglect with which that important mode of transport has been regarded in this country, and the different treatment that it has received from the most opulent and civilized of foreign nations, who are also our chief competitors in trade, it remains to consider whether we should rest content with things as they are, or seek for a means of reviving canal traffic.


MILLIARDS.
FIG. 1.—WATERWAYS.—TONS PER KILOMETRE.
MILLIARDS.
RIVERS
CANALS
RIVERS & CANALS


MILLIARDS.
MILLIARDS.
FIG. 2.—RAILWAYS.—TONS PER KILOMETRE.

It is shown that the transport of goods within the kingdom is far greater in quantity than the external transport, that railway rates are higher than elsewhere, and that there is no hope of a general reduction in railway rates being obtained.

On the other hand, Parliament has recognized that railways ought not to own canals, and has given effect to this opinion by passing the Act of 1889, which compelled the Manchester, Sheffield, and Lincolnshire Railway Company to sell the canals between Sheffield and the Trent to an independent canal company to be created after the passing of the Act. The Report of 1872, previously referred to, also recommends the amalgamation of existing canal companies, and we have seen that this has been acted upon by the Grand Junction Company which has obtained an additional 48½ miles of waterway for the small sum of £17,000.

So far, these are the chief results that have followed the Report which emanated twenty-three years ago from a committee containing many eminent members of both Houses of Parliament.

The rate of progress is too slow, the reasons being, firstly, the Report was in advance of the opinion formed by the general body of traders who at that time took but little interest in the "canal" question, the conditions of trade being then very different from what they have been since and still remain. Secondly, the difficulties in carrying out the suggestions are very great; and farther, without capital being secured for improving the waterways, their freedom and amalgamation would only half fulfil the needs of the community.

If a powerful railway company is to be at liberty to use to the full extent all the opportunities afforded by our Parliamentary proceedings for preventing the acquisition of a railway-owned canal by an independent proprietary, we need not wonder that there is no general response made to the invitation given by the committee.

It is very seldom that so powerful a combination of interests as that formed in Sheffield in 1889, can be induced to act together in a matter of this sort, and, after a delay of six years, only a portion of the capital, required for the purchase of the canals, has been subscribed. This leaves the railway company with a preponderating interest in the capital account and a majority on the board of directors.

It appears to the writer to be necessary to obtain an expression of opinion from trading communities and corporations that water-carriage must be treated as a matter of real importance to trade, and that this should be made with sufficient vehemence or urged with sufficient force to compel attention at Westminster.

The Association of the Chambers of Commerce of the United Kingdom have at five meetings, including that held at Huddersfield in 1894, passed resolutions advocating the compulsory purchase of canals by the Government. This is one solution of the difficulty, and appears to many thoughtful people to be the only satisfactory solution likely to be obtained.

The Government will never adopt a proposition of this sort without previous enquiry, and in the writer's opinion the best method of proceeding would be to obtain a Commission, very similar to "The Royal Commission on Public Works in Ireland," which was appointed in 1886, and on whose report the Light Railways (Ireland) Act was passed in 1889. The Commissioners were the late Sir James Allport, Mr. Abernethy, Mr. Wolfe Barry, and Mr. J. T. Pim. Their powers were drawn widely, and the result of their enquiry was a very valuable report on the public works of Ireland, and more particularly on the railways, which is well worth careful study. It has always appeared to the writer that railways in Ireland and canals in England had certain features in common.

The commissioners found that there were forty-one railway companies with a total of 2,991 miles, only 611 miles of which were double line, that fourteen companies had less than 100 miles of main line, and that the average was only 135 miles per company. Owing partly to this, they found the percentage of working expenses excessive, viz., 55 per cent. of gross receipts, compared with 53 in England and 50 per cent. in Scotland. They advised amalgamation, and estimated that a saving would be effected of £40,000 per annum in working expenses and £55,000 in management, making a total of £95,000, equal to 6½ per cent. of the net receipts of all the railways.

The reference to an English Commission on canals should be widely drawn, and include the consideration of purchase by the Government, as well as the provision of simple but equitable means for the transfer of canals from railways to independent companies, and for the amalgamation of canal companies among themselves, with a proviso for exercising compulsion under certain conditions if it were found necessary. The provision of funds for the improvement of canals might be made on the lines of the Bill of 1861, "To facilitate the construction and improvement of harbours" by authorizing loans to harbour authorities by the Public Works Loan Commissioners, who are empowered to lend money at 3¾ per cent. for the purposes of the Act. In consideration of the reduced value of money, the rate of interest might now be fixed at 3 per cent.

Without more minute information as to the amount of traffic that is carried from place to place by railway and canal, it is impossible to

dogmatize on the question of improvements. All canals should be compelled to allow steam to be used. To quote a very apt phrase used by the *Times*, "if one were obliged to condense the history of the nineteenth century into a single word, that word would be steam," and yet on the majority of the canals at the end of this century, steam is never seen, and on many it is prohibited, unless the sanction of the Board of Trade is obtained, and this may involve in many cases an additional toll. Surely that fact alone is an indication of the parlous state of the canals in this country. Uniformity of gauge must also be aimed at. It is a fortunate circumstance that the locks for considerably more than two-thirds of the total mileage are wide enough for barges of the width of the standard French barge. Locks to accommodate trains of four barges of the present type would be a *sine quâ non* on an improved canal.

It would be useless to expend money on improvements except on main routes, and the first to be taken in hand should be the line from London through Birmingham to the Mersey, which would link the trade of the Thames and the capital of the country with the thickly populated Midlands, and the Midlands with the ports of Liverpool and Manchester.

The improvement of canals is a question of more immediate importance to the inhabitants of Birmingham and district than to any other community. They occupy a central position, and are now compelled to import raw material in large quantities from the coast and require cheap carriage both for exports and imports. The question is of scarcely less importance to the members of The Federated Institution of Mining Engineers, for undoubtedly on a canal system in harmony with the requirements of the trade of this country the bulk of the traffic would be in coal and other heavy minerals, requiring coal to reduce them to a manufactured state.

The writer hopes that, after discussion by the members, a resolution will be passed which will claim attention from the "powers that be," and lead to strenuous efforts being made to place the canal system in the condition of rendering good service to the trade of the country.

The resolution suggested for your consideration is as follows:—"That having regard to the urgent need for utilizing more fully the canals of this country, the President of the Board of Trade be asked to call for a return, giving particulars of canals, and the traffic thereon, for the year 1894, and be requested to receive a deputation from this Institution with a view to the appointment of a Royal Commission to consider the whole question of inland navigation; and that Members of Parliament be invited to join the deputation."

The following paper by Mr. J. A. Saner on "Canals" was taken as read:—

CANALS.

BY J. A. SANER, ASSOC. MEM. INST. C.E.

Everyone is now quite aware that, unless the canals are greatly improved both in size and uniformity, they will never be able to occupy the important position, as means of communication, which they should and would do if properly and systematically arranged.

Although the author knows that many men of great experience contend that canals worked in conjunction with railways could not be made either to pay or to allow the railway to pay, he cannot but hold the view, if the canals were of sufficient size, and as uniform in gauge and capacity as the railways are, that they could be worked side by side to mutual advantage, largely doing away with the goods train, and saving the risk of accidents which now, unfortunately, are so often attributable to the shunting and other operations incidental to goods traffic. The canal would take the bulky and heavy traffic, such as coal, iron, heavy machinery, stone, etc., and the railway would take the passengers and other perishable and light articles, on the principle that, as the writer heard an engineer once say, "you do not carry a bale of cotton on a hansom cab, nor hire a lorry when you want to catch a train."

The writer proposes, therefore, to explain as briefly as possible his ideas as to the most suitable dimensions for an uniform system of canals in this country, and as to the method of working them; the ideas being based on his experience of the river Weaver, with which he is intimately acquainted, and on the other rivers and canals through which he has either passed or been brought in contact.

Of course, he is leaving out of consideration large ship-canals, such as the Suez, Manchester, or Gloucester canals, the conditions of which are only applicable in few instances, and scarcely come under the heading of inland navigations.

The chief disadvantages of canals are that—

(1) The rate of transit is comparatively slow as compared with railways.

(2) The liability of freezing in winter, and disorganization of traffic ; and

(3) Generally the goods require lifting out of the boats, and therefore require special appliances for discharging.

On the other hand, canals have the advantages that—

(1) Goods can be carried in greater bulk.

(2) The boats can load and discharge at any point on the banks without the risk of collision or construction of sidings.

(3) For fragile, or partially fragile articles, such as bricks, pipes, light castings, etc., there is less liability to breakage ; and

(4) The cost of carriage by water is less than the cost by rail.

The first and second disadvantages can now be overcome for all practical purposes—at any rate, during a normal English winter—by the use of steam or other power engines, instead of the manual and horse-power at present employed for hauling ; but the use of steam necessitates a larger sectional area of waterway, and the thorough protection of the banks.

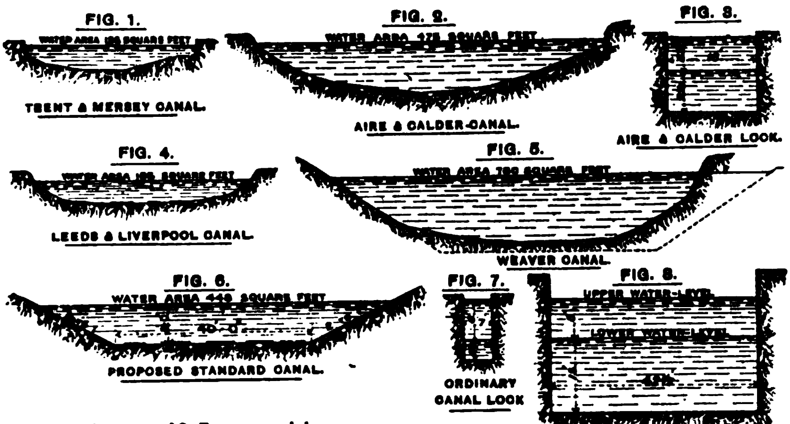
The slow progress on a canal is also largely due to the necessity of passing through a lock at each change of level, and although a railway train stops at numerous stations, it is possible to run the express trains for any required distance without stopping; whereas on canals, unless the traffic is confined to short lengths, the lock-delays are the same whether the traffic is so-called express or not. The chief considerations, therefore, to be taken into account in laying out a canal are that the changes of level may be as few as possible, without making the course too long and winding, and the provision of means for overcoming changes of level of considerably greater height than those now existing.

The third disadvantage is one which can be overcome by suitable machinery, and is almost equally applicable to railways, many articles requiring the use of a crane, whether they are being loaded or discharged from either a boat or a truck. The steam canal-boat has even an advantage in being able to carry a mast and derrick attached, for loading and discharging. Nearly all the Weaver boats are so fitted, and excellent results are obtained.

Dimensions of Canals.

In constructing a canal, or canalizing a river for rapid transit, it is essential that the sectional area should be ample, it being well known that, within certain limits, the greater the ratio of the sectional area of the

waterway to the sectional area of the boat, the less the resistance; this was very forcibly brought before the writer during a tour he made through some of the English waterways, when he found that in the Weaver, Severn, and Thames, his launch travelled easily 11 and 12 miles an hour, while on the narrow Trent and Mersey, Worcester and Stafford, and Oxford canals 4 to 5 miles was the extreme speed that she could attain.



SCALE - 40 FEET TO 1 INCH.

The Weaver has a depth of 11 to 12 feet and a sectional area of 780 square feet, while the canals have a depth of 3½ to 5½ feet and a sectional area of about 130 square feet. The ordinary traffic on the Weaver is carried in 250 to 300 tons barges and steamers, whose draught is 10 feet and beam 20 to 21 feet amidships; these vessels travel in the open lengths, when not towing, at a speed of 7 and 8 miles an hour, while on the canals the ordinary boats which do not carry more than 25 to 30 tons, with draughts of 2½ to 4 feet, are towed by horses at a rate of 5 to 6 miles an hour.

In France, where the question has been thoroughly investigated, the standard dimensions for a canal are: bottom width, 32½ feet; depth 6½ feet; and a sectional area of about 297 square feet. This standard canal would not be applicable in England on account of the size of the existing boats, and in 1893, in a paper read by the writer before the Liverpool Engineering Society, he advocated that the English standard canal should be: 40 feet bottom-width, 64 feet top-width, 8 feet depth of water, and 416 square feet of sectional area. Such a canal would accommodate vessels 75 feet long, 18 feet wide, 7 feet deep, and of about 210 tons displacement. It has been recently shown by Mr. Mars at the Sixth

International Congress on Canals, that there would be no difficulty in increasing the length of the boats, provided the locks and curves allowed it to be done, and provided the rudders were made of suitable size to give sufficient steering-power.

The new canals being constructed in Germany are: 46 feet in bottom-width, 76 feet in top-width, and 6½ feet deep, with 396·5 square feet of sectional area. These canals allow the passage of vessels 172 feet long 23 feet wide, and drawing 5¾ feet of water, which corresponds to a, carrying capacity of 400 tons. The writer sees no reason why the proportions of a narrow-boat, as they are now called, should not be followed in the larger sizes. These boats are 60 to 70 feet long by 6½ feet beam, or a ratio of length to breadth of about 10 to 1. If this ratio were adopted the carrying capacity of a canal of the given sectional area would be much increased, and each boat would be capable of carrying at least 300 tons of cargo.

Protection of Canal-Banks.

The question of the protection of banks of canals may now be considered, and here there is a general concurrence of opinion that if rapid transit is to be achieved and steam or other mechanical power used, the only effective way is to pave the sides throughout, with either stone or concrete, for a considerable distance above and below water-level; and although it is not necessary where such protection is thoroughly done, it is an advantage to form a "berm" or shelf a few inches below water-level, upon which the force of the waves may be expended. This protection necessitates a wider strip of land being purchased, a cost which cannot be thought of where large towns or other circumstances make the land of great value. The writer's experience so far shows that the action of the water does not extend much below the trough of the wave formed by a steamer when she is keeping her course down the centre of the waterway, but it is often the case that vessels in passing or when drawn up for loading and discharging, work their propellers near the bank, and in such cases a hole is formed below the foundations of the wall. This action of the propellers is so powerful, that on the Weaver the writer has frequently removed a shoal by mooring tugs and working the engines against the mud or sand, with good results; so that, if absolute immunity from slips be desired, the foundation of the protecting-wall should be below the bottom of the canal. There is no doubt that a slope pitched with rough-dressed stone backed with "scabblings," and having a good batter is the most desirable form of wall. Many hundreds of feet of this description of

work exist on the Weaver, built of red sandstone, more than fifty or sixty years ago, and it is seldom that any defect occurs except through undermining. Concrete would form a good protection, though if it were not made of considerable thickness the small settlements which always take place in newly-formed banks would cause it to crack and become very unsightly, repairs only adding to the disfigurement. Where stones are used any subsidences can easily be repaired.

The system largely used on the Weaver is to drive small wattling-piles, 6 to 8 feet long, and to fill the hole behind with broken stone, or bricks, or clinkers from the salt-works, placing a longitudinal plank so as to prevent the material from slipping through. These planks are bedded down as low as possible, and the slope is either paved with clinkers or soiled over. The clinkers are sometimes set in hydraulic mortar, and, if they are hard and well selected, will last for many years, although in many cases it has been found that the action of frost causes them to decay more rapidly than the mortar, leaving a honeycombed slope. In any case, clinkers are easily dredged out if they fall into the water and form no danger to traffic; they are also cheap, the cost of protecting the banks in this way varying from 1s. to 2s. 5d. per foot.

On a river like the Weaver, where it is not possible to draw down the water for repairs, the above-mentioned method acts very well; but in building a new canal, the writer would certainly recommend one of the more substantial forms of protection.

When the canal passes over an embankment or through very porous soil, it is necessary to case it with clay-puddle to prevent the water from oozing through, but this has seldom been found necessary in the case of the Weaver, where, although it is raised in several places considerably above its normal level, no puddle has been used. This is probably owing to the position of the river in its own valley; but on several occasions the writer dammed off the water with merely an embankment of sand, which acted admirably, showing that the percolation is not so great in that material as sometimes imagined, and points to the possibility of dispensing with clay-puddle in many cases. In these sand-dams it was, of course, vitally necessary not to allow the water to flow over the top, as immediately it did so, the whole embankment was washed away.

Where special wharves are required, they should be built with solid masonry or concrete walls, or where it is impossible to lower the water so as to obtain a suitable foundation, timber-piling may be used, which, if properly tied back with iron rods, will serve well as a wharf for from fifteen to thirty years, according to the quality of the timber and the strength of the work.

It is always advisable to use timber of ample dimensions, as the labour of driving is very little more, and it is very difficult to efficiently repair work of this nature without drawing the old piles and remaking the wharf, especially when heavy buildings are near the edge.

Another reason for abnormal strength is that the watermen will fasten their ropes to the piles however much they may be cautioned to the contrary, and however well the wharf may be provided with suitable mooring rings or posts. There is thus often a considerable strain, especially with large 200 to 300 tons crafts.

Locks, Etc.

The next important feature to be considered is the method of effecting the changes of level from one pound to another, and here there are still many opinions as to the means to be adopted, owing to the difficulty of dealing with the heavy weights to be provided for, and the necessity for economy in time, and in the use of the water in most canals. At present there are three methods of overcoming the difficulty which have been tried on a large scale:—

1. The ordinary lock which has been in use from time immemorial.
2. Inclined-planes or ship-railways, by which a large tank full of water, supported on wheels, is drawn up an inclined railroad, or the boat is drawn out of the water and carried in a cradle.
3. Hydraulic-elevators, in which the tank is supported and lifted vertically by means of hydraulic power actuating a single ram, similar to those at Anderton on the Weaver, Les Fontinettes in France, and La Louvière in Belgium.

As before mentioned, the fewer changes of level in a canal the greater is the speed with which it can be worked, and in undulating or hilly country the number of locks in the existing canals is so great that a large percentage of the total time taken to navigate from one point to another is occupied in locking through.

A very good example of these delays may be experienced by travelling along the canal from Worcester to King's Norton, where there are no less than 57 locks; and in 1891, when passing through in a steam launch, it took the writer ten hours and twenty-one minutes to travel 21 miles, or an average speed of 2 miles an hour, the total height to be overcome being 428 feet.

The features of a lock are so well known that they need not be described here, for a moderate fall (say 15 to 18 feet) it would be difficult to improve them, both as regards ease of working and cheapness of first

cost; but when the fall exceeds these heights the commotion caused by the rush of water is liable to seriously endanger a small boat, and to cause a larger one to strike violently against the sides and gates. Numerous expedients have been suggested for overcoming this difficulty, and an arrangement was devised for the Panama canal-locks by which the orifices for filling and emptying were distributed over the bottom and sides in such a way as to break the force of the water. This design may succeed when everything is new and the lock is of large area. It would greatly increase the cost of the works, and in time the small passages would be liable to be partly blocked by the mud and detritus which is drawn into the culverts, and thus impede the flow of water. On the Manchester ship-canal and the Weaver, the culvert-openings are distributed along the side-walls, the size of the openings, however, being so large that nothing can possibly get stuck. Even then, with a fall of only 16 feet, which is the deepest, great care is necessary to prevent damage to small craft during the filling of the lock. The loss of water in deep locks is also excessive, especially when the traffic is all going one way, and though on a river like the Weaver it is very seldom that there is a scarcity of water, on artificial canals this is a great consideration, making it imperative in dry seasons to delay the boats until they can be alternately raised and lowered.

At the Fourth International Congress on Inland Navigation a design* was brought forward for a lock of 65 feet (20 metres) fall, in which the difficulties of commotion in the water, and excessive loss, were overcome by side chambers at different levels, which stored three-fifths of the total quantity. The lock, which was of the French standard size, was estimated to cost £36,000, and to pass a boat through in less than twenty minutes. Even in this case the loss of water at each operation was 26 feet (8 metres) in depth, and would seriously draw upon the supply in a summit pound.

Inclined-Planes.

The writer has not had any personal experience of inclined-planes, but would urge that the easy gradient required would frequently necessitate more land than was available, and the oscillation would cause the boats to strike against the sides of the troughs.

At the Fourth International Congress on Inland Navigation, a scheme was also submitted for an incline of 98 feet (30 metres) in height to carry the French standard boats; but the estimated cost was £60,000, which is very much greater than that of the lock with 65 feet (20 metres) fall and scarcely in proportion. The wear and tear of the parts would be

* *Report*, page 21.

considerable, and the chains or ropes connecting the two troughs would require constant overhauling and examining. The most extensive use of planes, that the writer knows of, is on the Oberland canal in Germany, where there are five in succession, with lifts varying from 45 to 80 feet. The boats are only of 60 to 70 tons burthen, with flat bottoms, and are not kept afloat, but rest on a grid for nearly their whole length. This system does not appear to be applicable for larger craft, as the weight of the cargo, especially if in bulk, would set up severe strains upon the sides of the boats when taken out of the water. The cost of these inclines averaged £5,140 each.*

Lifts.

The third way of solving the problem is by means of vertical hydraulic lifts. The first of these was built at Anderton in 1874-5, by the Weaver Trustees, acting under the advice of Mr. (now Sir) E. Leader Williams. This lift (which is described in detail by Mr. Sydenham Duer †) raises and lowers the canal-boats through a height of 50 feet between the river Weaver and the Trent and Mersey canal, being connected with the latter by a wrought-iron aqueduct. The boats are enclosed in a water-tight trough, and remain afloat during the whole operation. The same principle has since been adopted, as before mentioned, in France and Belgium for vessels of much larger dimensions.

The writer has now had ten years' experience of the working of the Anderton lift, and cannot speak too highly of its efficiency, although no doubt as it was the first of its kind, it has been possible to improve some of the details of construction in those more recently built.

The caissons or troughs are capable of holding two of the narrow boats in use on the canal, and the operation of entering, lowering, and opening the gates and passing out can be performed in from ten to twelve minutes. The waste of water is 6 inches deep over the area of the trough, eleven-twelfths of the stroke being performed by means of the weight of this water, and the remaining power being supplied by a small engine working an accumulator.

As the lift has two troughs which are in equilibrium until the 6 inches extra of water is put in, one always ascending, and the other descending, it is ready for either up or down traffic, and when vessels from both sides arrive at once it acts as a double lock.

* *Foreign Office Report*, 1894, No. 345.

† *Proceedings of the Institution of Civil Engineers*, vol. xlv., page 107.

The objection raised to such lifts is their first cost and cost of maintenance, but when the number of locks which they replace is taken into account the difference of the former is not so very great, while the advantages to the traffic and the saving of time and water should fully compensate for the cost of the maintenance. The cost of the Anderton lift, with troughs 75 feet by 14½ feet, was £50,000; the cost of Les Fontinettes lift, with troughs 131 feet by 17 feet, was £60,000.

Supposing that in the first case five locks each of 10 feet fall had been built, they would have cost from £6,000 to £8,000 each, and the canal company would have raised insurmountable objections to the loss of water. The cost of maintenance chiefly consists in wages to the attendants. At Anderton, there are four labourers, one engine-driver, and one man in charge of the valves, which control the rams, he being also responsible for everything outside the engine-house, and stationed on the upper level, giving his orders to the driver by means of a speaking-tube. The total average cost of maintenance, including wages, coal, stores, and repairs averages £500 per annum, which amounts to about 1d. per ton on the traffic now using the lift.

It is, however, capable of carrying a very much larger number of boats than are passing at present, and if we allow four lifts an hour, with two boats each lift, carrying an average of 20 tons to each boat, and ten working hours per diem, the staff would remain the same, and the cost would only be 0·2d. per ton. Neither of these calculations takes into account any return traffic, which may be either light or laden, and would in a through route be in many cases the latter.

If the alternative system of five locks were adapted to modern requirements, with turbines for moving the gates and sluices, it would not be possible to allow any "bargee" or stranger to interfere with the machinery, so that at least three or four men would be required to be in constant attendance, and as the time taken to lock through would be equal to five times that required for the lift, the amount of tonnage would vary accordingly, and the capacity of the canal be lessened in a like manner.

It is, of course, questionable how long such a lift can be kept working in severe weather. The pipes and cylinders are, of course, either underground or properly protected against frost, but there is a certain danger that the icicles which form at the gates will prevent the joint from being properly made, and great care is necessary at such seasons. The writer has tried a steam jet to remove the ice at the joints, but with only partial

success. However, during the writer's experience, the lift at Anderton has always been able to work until the canal was so full of ice that the traffic thereon had ceased.

The above facts certainly lead to the conclusion that for the canals of the future, with their steam and rapid traffic, lifts similar to those just described offer a feasible and economical solution of the problem of changes of level.

As before mentioned, the greatest drawback to the English canal-system has been the want of uniformity, and this is especially marked in the size of the locks. A glance at the Board of Trade return of 1888 will show that there are scarcely two canals with the same dimensions of locks, and that in no case is a through route available except for the smallest class of boats. In the paper read by the writer, before the Liverpool Engineering Society, he urged that a very good standard for locks or lifts would be 150 feet by 18 feet by 7 feet, and he did so for the following reasons :—

The standard lock adopted in France is 131 feet by 17 feet by 6½ feet; but in England this gauge would necessitate a fresh standard of boat, otherwise a large waste of water would take place each time any of the present boats used the locks. On perusing the same Board of Trade Return it will be found that 80 per cent. of the boats now in use could be economically passed through such a lock as the writer has suggested. The narrow boats would pass through four at a time and the "dukers" or "wiganners," or whatever local name they may be known by, would pass through two at a time, while if boats of proportionate dimensions to the narrow boats were built, they would be able to pass through one at a time with a cargo of 300 tons. It will probably be objected that hydraulic lifts could not be constructed of such dimensions, but those already in use in France are 131 feet long, and the possibility of constructing a tank of much larger dimensions than these, supported on a central-pivot, has been amply demonstrated on the Manchester ship-canal, where the movable portion of the Barton swing-aqueduct weighs no less than 1,600 tons and is 234 feet in length.

Bridges.

There is another form of annoyance and delay to canal traffic in the numerous opening-bridges, which exist in many places, and have to be worked by the boatmen. It is, of course, possible, under existing circumstances where the boatman is well in advance of his boat, to dispense with regular attendants, but with steam-traffic towing barges it is necessary to

have attendants to open each bridge, as the delay of stopping and restarting would be insufferable. The only method of avoiding this annoyance and expense is to have fixed bridges, and as the boats using a standard canal would be able to lower their funnels, masts, and derricks these bridges need not have a greater headway than 16 or 17 feet, which would allow of light craft easily passing under. There would therefore be very few places where an opening-bridge would be necessary.

Artificial Lighting.

To make full use of a waterway the traffic should be able to work both night and day, otherwise it is seriously hampered in its competition with railways as regards speed.

It would be possible now by means of electricity to light a canal on the same system as a street in a town is lighted, but the cost of so doing would be enormous, and in the writer's opinion unnecessary on such a canal as he has been describing. On the Weaver, the traffic works night and day without any artificial lighting whatever, so much so that near the locks and bridges any lights in the lock huts or on the roads are carefully shielded, as the watermen complain, and justly so, that they are blinded by them. Unfortunately, the Anderton lift is only worked during the day time; had it been worked all night there would have been valuable experience as to the possibility of using these lifts without artificial lighting.

As it is now, however, there are frequently boats passed up and down in the early and late hours of the winter months without difficulty beyond extra carefulness.

The writer has often stood near the wheel of a river-steamer when running in the dark, or watched them passing from the shore, with a view to forming a judgment on this point, and as far as the open reaches of canal are concerned, he would certainly prefer to be without lights of any kind. As to deep cuttings, or the approach to locks or lifts, especially the latter, he is inclined to think that powerful lights, placed on high masts, and carefully shielded on the up-and-down stream sides, would prove an assistance rather than a detriment to the boatmen. On a canal where there was sufficient water, the power for these lights could be obtained by turbines, or in the case of lifts a small engine could be worked from the boilers.

Cost of Carriage.

The writer stated that a fourth advantage which canals had over railways was the cheaper rate of carriage, but having no personal connexion with railways, he had found it most difficult, not only to obtain reliable

figures, but to form any tables from which averages might be taken. He had therefore been content with working out the cost of carriage by canals, for which he had ample data, and he thought that if the railway charges were no heavier than those he quoted, that they would hear very little complaint of their being exorbitant.

The writer has been obliged to choose some specific route for his calculations, and he has taken the proposed new canal from Birmingham to the Weaver as a basis.

They were all no doubt aware that for some time it has been proposed to construct such a canal to pass through Wolverhampton and the Potteries to Winsford on the river Weaver, which latter runs through the salt districts of Cheshire, and is connected to the Mersey and the Manchester ship-canal at Weston Point near Runcorn. That such a canal would not only be a great source of convenience and economy to the trader, but also a remunerative undertaking to the promoters, he had been convinced ever since he knew the districts concerned, and he only hoped that as soon as a reasonable opening occurs, the subject would be taken up by the inhabitants of Birmingham and Wolverhampton districts with all the energy which usually characterize their conduct of business.

Suppose, then, that this canal, which would probably be somewhat on the standard lines just laid down, is *un fait accompli*, and that the estimated cost has not been exceeded to any large extent.

The canal company might or might not act as their own carriers; in many cases it would pay the large trader to have his own craft, but whosoever owned the craft, the cost of working would be the same.

In these estimates the writer has not included any terminal charges or dock dues, which would be the same in any case, except when the trader was fortunate enough to have his works situated on the banks of the canal. To enable the canal to be fully utilized, the boats must be of the largest possible dimensions, and should work in trains of three or four at a time.

The writer has therefore taken a train of one steamer and three barges, with an average capacity of 250 tons each, and a total of 1,000 tons; this would be equal to 100 railway-trucks of 10 tons capacity, and forms a most convenient minimum for a train of vessels. Such a combination would be equal to the trains of craft now using the Weaver.

Statement showing estimated cost of conveyance by canal:—

First cost of plant for 1,000 tons—	
Steamer of 250 tons	£3,000
3 Barges of 250 tons each ...	4,500
Total cost	7,500

Cost of one voyage and return empty (if a return cargo were obtained some of these items would be lessened) on the basis of three trips per fortnight, each trip conveying 1,000 tons—

	£	s.	d.
Steam and bargees wages, including ton-money and other extras	20	19	4
Canal toll, 60 miles at $\frac{3}{4}$d. per ton per mile	187	10	0
Weaver toll, 20 miles at $\frac{1}{4}$d. per ton per mile	20	16	8
Upper Mersey dues, say	0	10	0
Total charges	229	16	0

The cost of 70 trips per annum conveying 70,000 tons would be—

		£	s.	d.
Cost of carriage		16,100	0	0
Maintenance, steamer, say	£150 0 0			
" barges	90 0 0			
		240	0	0
Depreciation at 5 per cent		375	0	0
Interest on capital at 5 per cent		375	0	0
Total charges per annum		17,090	0	0

These charges would be equal to, say, 4s. 11d. per ton carried the whole distance, or 0·61d. per ton per mile.

If the canal had not the advantage of the rivers Weaver and Mersey the cost would be, omitting pence—

	£	s.	d.
Steamers and bargees wages, say	21	0	0
Canal toll, 98 miles at $\frac{3}{4}$d. per ton per mile	306	0	0
Total charges	327	0	0

The cost of 70 trips a year, carrying 70,000 tons would be—

	£	s.	d.
Cost of carriage	22,890	0	0
Maintenance	240	0	0
Depreciation at 5 per cent	375	0	0
Interest on capital at 5 per cent	375	0	0
Total charges per annum	23,880	0	0

These charges are equal to, say, 6s. 10d. per ton carried the entire distance, or say, 0·83d per ton per mile.

In taking $\frac{3}{4}$d. per ton per mile as the toll, a very high one has been taken, equal to the highest of the new rates chargeable on the Weaver.

In contrast to the above estimates the writer may venture to quote some figures taken from the present rate-book at Liverpool for railway-carriage between that city and Birmingham :—

	s.	d.	
Salt and coal			no rates in force.
Pig iron	8	0	per ton from station to station.
*Earthenware, in casks or crates ...	21	10	per ton, not carted at Liverpool.
„ in hampers	25	3	„ „ „
„ in boxes or cases ...	30	2	„ „ „
Woollen goods in bales, packages, or trusses	25	3	„ „ „
Machinery parts in cases, second class	21	10	„ „ „
Machinery not packed, third class, carrier's risk	25	3	„ „ „
Machinery not packed, at owner's risk	22	1	„ „ „

The question may be asked as to whether a canal between Birmingham and the Weaver, such as now referred to, would be a profitable undertaking to the promoters. Of this there can be little doubt, and to support this opinion, the writer has taken from the Board of Trade Returns for 1888 the following figures referring to existing canals. All named therein, with the exception of the Weaver and the Aire and Calder, are of the usual small size, so that it may be fairly argued that with improved accommodation and greater facilities the position would be at least as favourable.

Carriers.	Tons.	Net Revenue. £
Aire and Calder	2,210,692	112,796
Leeds and Liverpool	2,016,976	50,724
Bridgewater canals, now Manchester ship-canal	2,916,754	71,937
†Trent and Mersey	1,139,098	35,697
†Shropshire Union	1,124,598	4,473
Totals	9,408,118	275,627

or 7·03d. per ton carried.

Non-Carriers.	Tons.	Net Revenue. £
Birmingham canals	7,713,047	116,096
Regents canal	1,672,959	45,821
Stafford and Worcester canal ...	646,038	9,259
River Weaver	1,498,124	16,148
Totals	11,530,168	187,324

or 3·6d. per ton carried.

The gross totals of 20,938,286 tons and £462,951 show an average profit of 5·41d. per ton carried.

* Earthenware is only conveyed at owner's risk unless properly protected by packing.

† Railway-owned.

Five of the above canals are carriers and four non-carriers, and any new company would also act as carriers, at any rate in part, if not entirely.

The average net revenue shown in the above tables amounts to 5·41d. per ton per annum, and as the least tonnage which may be expected between the different points *en route* between Birmingham and Liverpool may be taken at 3,000,000 tons, there would be a net profit of £67,625 after paying all working and other expenses.

By choosing what may be termed the Weaver-Mersey route, not only would the whole of the iron and coal country of Wolverhampton and Staffordshire and the Potteries be passed through, but there would be direct inland waterway connexion between the three large cities of Birmingham, Liverpool, and Manchester, and the existing docks and quays would be available without farther expenditure.

The writer does not wish it to be thought that in this paper he is advocating any particular scheme; all he wishes to impress is that we are many years behind our neighbours, Germany and France, in our canal system, and are therefore hampered in trade to an equivalent extent.

The connexion of Birmingham and the surrounding populous neighbourhood with the seaboard by an improved waterway would be a suitable enterprise with which to commence a new era for canals. The existence of the rivers Mersey and Weaver and the Manchester ship-canal point to the most practical route being along their already-prepared channels.

Lastly, the writer is of opinion that the dimensions both of waterway and vessels laid down in this paper are such as would be very suitable for a standard system of English canals.

Mr. W. H. Hunter (Manchester ship-canal) considered that the revival of interest in, and the direction of attention to, the subject of inland navigation was one of the most hopeful of the economical developments of the present day, as it was, indeed, one of the most important. Without a really effective canal-system it was impossible to provide cheap carriage for either minerals or manufactured goods from the industrial districts of the country that lie at any distance from the seaboard, and without cheap carriage minerals must remain in their native strata, and manufactures must languish and ultimately perish. It was satisfactory to remark how the completion of the Manchester ship-canal, despite the formidable obstacles which were thrown in its way, and the

recent rapid increase of the traffic borne upon its waters, had given a stimulus to the reviving interest in inland canals, one of its results being an application to Parliament during the current session for power to construct a new waterway to Oldham and to Royton in the county palatine of Lancaster. It was important at such a juncture as the present that every effort should be made to guide the public mind, not only so as to lead to public interest in canal development, but so as to render that interest intelligent and practical. It could not be doubted that The Federated Institution of Mining Engineers was doing good service in its day and generation in offering opportunity for discussion on the structural necessities, as well as on the economic considerations which should govern in the new era which had been, to all appearances, already reached. The first of the structural necessities was beyond question uniformity of type. It was essential, in a small and thickly-populated country like Great Britain, that an effort should be made to arrive at a standard minimum sectional area of lock, height of quay, radius of curve, etc., which should be adhered to in future operations, whether in the construction of new canals or in the improvement of existing navigations. In this, he (Mr. Hunter) was in cordial agreement with Mr. Saner, and with those who had preceded him in the same recommendation. From the conclusions arrived at by Mr. Saner as to standard sizes, he (Mr. Hunter) was, however, obliged to differ. In a standard type there could not be a greater error than that of putting the standard too low or making the type too small. Hence, even though it might be necessary from monetary considerations (although there was undoubtedly a time of rebound coming when money would be freely offered for public works and for the development of the material resources of the country) to spread the operations of the development and the modernization of the canal-system over a longer term of years, he (Mr. Hunter) would regret to see any standard adopted, or type of canal section, or lock accepted that would not provide for the free passage of a steam-barge or packet carrying at least 450 tons of deadweight, and competent to aid in the coasting traffic of this country. The standard that would ultimately be adopted would necessarily be the desirable modified by the practicable. The issues involved in the determination of this standard size were so great, and the interests concerned so important, that the Government should appoint a Royal Commission to enquire into, and submit recommendations upon, the subject as seen in the light of recent developments. Having regard to the diminution of resistance to the passage of a barge, the form of the cross section of the canal was of importance. For a single waterway, *i.e.*, that adapted for the passage of

a single boat only, of any given size, it could be shown that the least possible resistance would arise when the area of the section was so distributed as to coincide as nearly as possible with the midship section of the boat, or, in other words, that the most advantageous section for a single waterway would be of a semi-elliptical form. It was, however, a primary necessity of an efficient navigation that two barges should be able to pass each other at any point of their journey; and a modification of the section must therefore be made by the introduction of a central parallelogram equal in breadth to the beam of the boat, *plus* due allowance for clearance. Farther, as it was in most cases impracticable to line the sides of the canal with rubble walls, a second modification was required, and slopes must be substituted for the curved sides of the ellipse. In forming these slopes it was desirable, with the view of obtaining the most efficient section with the least possible quantity of excavation, that the slopes should be made as steep as the nature of the strata would allow; and if this be done, and the bottom of the canal be dished in the manner suggested by the development of its section from the modified elliptical figure, it would be found that a maximum of efficiency could be obtained with a minimum of cost.

Mr. URQUHART A. FORBES wrote that he agreed with the opinion expressed by Mr. Wells as to the necessity for securing the freedom of canals from railway control and for promoting their amalgamation. He would, however, draw attention to the fact that the Railway and Canal Traffic Act, 1888 (Part III.), contained provisions which might, perhaps, be utilized for both these objects. (1) As regards railway control, section 38 empowered the Railway and Canal Commissioners to make orders for the alteration and adjustment of tolls, rates, and charges levied on the traffic of, or for the conveyance of merchandize on the canals controlled by railway companies, where it was proved to their satisfaction that such tolls, rates, or charges were calculated to divert the traffic from the canal to the railway, to the detriment of the canal or of persons sending traffic over the canal or other canals adjacent to it. And if the alterations required by the order were not made by the company within such time as it prescribed, the Commissioners might themselves make them. Section 42 also provided that in the event of the misapplication of a railway company's funds for the acquisition of any unauthorized interest in a canal, the canal interest purchased in contravention of its provisions should be forfeited to the Crown, the officers who permitted such application of the company's funds being made liable for their repayment to the company. (2) As regards amalgamation, he had already pointed out in his paper

that section 44 provided for the establishment of a clearing system. In addition to this, section 37 extended the provisions of the Railway and Canal Traffic Act, 1854, as amended by the Regulations of Railways Act, 1873, which required companies to afford all reasonable facilities for forwarding traffic, to canals; while section 43 expressly empowered canal companies to enter into contracts for the arrangement of through tolls, and for the collection and recovery by any one of the companies on behalf of themselves and the other companies interested, of the tolls, rates, and charges payable in respect of such through traffic. Lastly, section 41, which provided for the inspection by officers, appointed by the Board of Trade, of canals which had fallen into such a condition as to be dangerous to the public or to cause serious hindrance to traffic, taken in conjunction with section 45, which provided for the abandonment of canals which had thus become derelict, seemed to offer facilities for their acquisition by companies or public bodies who could afford to turn them to good account. Clauses 3 and 4 of section 45 empower the Board of Trade to transfer such derelict canals to "any persons, body of persons, or local authority," and by means of a Provisional Order, "to provide for the constitution of a body to manage the canal or any part thereof, . . . and for any other matters which may appear to the Board of Trade to be necessary or proper for carrying this section into effect." The case of the Ouse, mentioned by Mr. Wells, which was inspected under section 41 in 1890, offers an illustration of this point. Under section 45, any of the numerous public bodies or companies concerned in the river, or any combination of them, might, presumably, apply to the Board of Trade for a Provisional Order, transferring the control of the navigation to them. The provision, therefore, seemed worthy the attention of those who are desirous of developing through water-routes.

Mr. J. A. SANER (Northwich) wrote that he had read with very much interest the papers upon canal and inland navigation. He would like to ask Mr. Wells whether he had ever compared his map of the inland navigations with that published by Mr. Priestley in 1831? He thought that the comparison would be interesting and instructive, for as far as he had had time to compare them, he did not find that there had been any extensive additions to the canal-system since 1831; but, on the other hand, there were many which were marked as being derelict on Mr. Well's plan.

Mr. EMERSON BAINBRIDGE (Sheffield) said that the comprehensive papers on canals would prove of great value to the members of The Federated Institution of Mining Engineers. He thought that Mr.

Wells had put the gist of the matter in his valuable paper when he said that "railway companies do not compete in rates." Colliery proprietors know well the value of this important statement, but he might mention that of the railway companies of this country, twenty-two of them in 1894 paid dividends amounting to £1,800,000 higher than the previous year. At the present time, the railway rates for coal from the Midlands were of higher value than the value of the coal at the pit. The Railway Rates Act passed in 1888, was a positive disadvantage to the trade of this country. It put the railway companies into one block, and naturally they fought for their own interests, and colliery owners had only an occasional opportunity of obtaining reduced rates. The various papers seemed to suggest that water-carriage would be reverted to. He was associated with the South Yorkshire canal, and had taken advantage of the recommendation of the committee, which met in 1872, referred to by Mr. Wells. The Sheffield Navigation Company had purchased the canal which goes from Sheffield to the sea. It had taken them twenty-two years to carry out the recommendations of the Parliamentary Committee which met in the year 1872. Mr. Wells mentioned the great advantage which lay in the width of a canal, and it would be very useful to know whether he would recommend that the extra width of the Weaver canal should be applied to all canals. He might also mention the relative speeds and costs of horse and of steam-haulage, as there was doubtless a very marked difference between the two. Mr. Wells had recorded some very interesting figures with regard to the growth of canal traffic in France, the user of canals at the present time being 84 per cent. as compared with 41 per cent. thirteen years ago. Probably instead of having a similar increase in England in favour of the canals, the ratio was much the same as thirteen years ago. On the general question of English trade, he thought that all would agree as to the desirability of cultivating foreign trade, and one of the great drawbacks was the rate for carriage in this country as compared with different parts of Europe and America. The difficulty of the Government acquiring the canals of the country was mentioned in the paper. One could imagine what an immense resistance would be exerted against it by the railway interest, but it was one of the remedies for the development of foreign trade against our own, and he trusted that one of the results of these papers would be to bring the question forward: namely, whether this mode of increasing English trade by acquiring the canals could be brought home to the present or some future Government.

Mr. M. H. Mills (Chesterfield) said that there were very many practical difficulties in connexion with the use of canals. One was the

question of transhipment: with a tender coal that was a very serious matter. There were not many collieries adjacent to canals; and it would not be a small matter to make a canal to every colliery. It would be better to consider what could be done to improve the railways before they thought seriously of spending large sums of money in making canals. Some collieries had been very successful owing to the facilities afforded by water-carriage. Perhaps Mr. Wells could afford some information on the subject of shipping coal into canal-boats.

Mr. JEREMIAH HEAD (London) said that having recently been in the United States of America investigating railway matters, he was in a position to confirm what had been said about the very much cheaper rates at which freight-traffic was carried there than in this country. He had analysed several of the rates from the town of Birmingham, in Alabama, a great iron district, to different points of consumption to which they sent their traffic, and he found that they worked out generally from about 0·25d. to 0·20d. per ton per mile. The American manufacturers consequently had an enormous advantage as compared with manufacturers in this country, where, as might be seen from Mr. Wells' and other papers, the rates vary from 1d. to 1·4d. per ton per mile. It was a preposterous thing that companies which were created by Act of Parliament for the purpose of carrying goods and passengers by railways should ever have been allowed to acquire the waterways and the rights to carry traffic in any other way, and this legislative oversight had led to all the trouble. He did not think, however, that the remedy was to be found in the State purchase of all the canals. That would mean the placing of a large amount of national money into property of very doubtful value, and he was quite sure that the State had plenty to do in fulfilling its legislative and administrative functions without becoming the owner and manager of property of that sort. He agreed with the last speaker, who suggested that we should consider "what could be done to improve the railways." We might also consider why it required such a large amount of money in comparison with other countries, especially the United States, to haul goods along our lines. In the first place, it was well known that English railways had cost, roughly speaking, three times as much per mile as they had cost in the United States. This enhanced cost was due to the Government and the Board of Trade and other bodies requiring that no railway should be made at all unless it was made almost perfect, and that all branch lines should be as well made, and worked as safely as any of the main lines. That reason alone made all English railways very costly. Another great burden was the cost of

Parliamentary procedure in getting the right to make a railway. This, and the enormous amount of money that had been paid for land when taken compulsorily, had made railways exceedingly dear in this country as compared with the railways of other countries. If English railways cost three times as much per mile as those of America, there was three times the interest required upon capital, and three times the rates in order to pay that interest. The American railways worked such traffic as the haulage of coal from Wigan to London, much more cheaply than English railways. One of their methods was to use trucks weighing 9 tons, which carried 30 tons, giving a tare of 6 cwts. per ton, instead of trucks weighing 5 tons carrying 10 tons, and giving a tare of 10 cwts. per ton. There was no reason why coal from Wigan to London should not be carried in the big American waggons which carry the traffic at so much less tare. In deadweight, in which canal traffic had the advantage of railway traffic, the weight of the boat was less material, as it was floating in water; but dead weight was of great importance in railway traffic. If they succeeded in establishing water-communication throughout the country in such a way as to bring competition to bear upon the railway companies and to compel them to reduce their rates to a third of what they were now, it would be a very doubtful advantage. The result would be to reduce present railway property to something like one-third of its present value; to reduce the income of railway shareholders to one-third, and in addition, an immense sum of money would be spent in laying out canals throughout the country. We should spend enormous sums of money so as to depreciate the value of existing property. Whether that would redound to the benefit of the country in the long run was doubtful, consequently he was of opinion that an endeavour should be made to work railways more economically. They could not undo the past, but he thought that the canals should be released from the railway companies, and facilities should be afforded to independent companies to take them up and work them wherever it appeared advantageous to do so.

Mr. T. Forster-Brown said that these papers on canals contained valuable information. Mr. Wells mentioned that in France the use of canals per mile was now 84 per cent. of the user of railways, whereas in 1882 it was only 41 per cent. He thought this statement was inconsistent with the following remark: the railway carriage had increased to 7,575,000 ton-miles, and canal traffic to 2,255,625 ton-miles. The canal question, whether looked at from the point of view of Mr. Bainbridge or of Mr. Wells, was a question of expediency. In some districts, if the canals were

relieved from railway control, by improving them they might be made extremely valuable for the carriage of merchandise and minerals for local consumption. It was quite evident that for carrying large quantities of coal, either for short or long distances, where speed was an essential element, improved canals could never take the place of railways. The real solution was the introduction of competing railways for the carriage of coal. He had had some experience in South Wales, where the rates had been reduced by railway competition from 0·75d. or 0·80d. per ton per mile to under ½d. A railway laid out with greater economy than the old railways might be made in many districts to carry minerals at a lower rate than the existing rates. There was one difficulty in reducing the rates, as against what one speaker said about the weight of trucks. Nearly all minerals were carried short distances, and carriages would be required for long distances as well as for short distances. He thought that existing canals not under railway control should be improved, and steam-haulage adopted; and then if good results were obtained Parliament should be asked to sanction the transfer of the possession of those other canals which were essential for competition from the railway companies.

Mr. G. E. Coke (Chesterfield) said that several speakers had spoken about the cost of traffic on the railway companies' lines being due to the increased cost of construction of English railways over those of foreign countries. He did not think that could be the actual reason, because on looking at the prices of railway shares he found that they often stood at from 50 to 100 per cent. above the cost of construction or of their original capital. It was quite evident that, though the cost was more than that of other railways, the traffic enabled them to pay dividends, which had enhanced the value of the shares considerably above the original cost. He had been lately engaged upon the question of the acquirement of the Trent navigation by the Corporation of Nottingham. The Traders' Association had prepared an interesting table, which showed the different rates charged by the railway companies where there was independent canal competition from where there was none; and railway rates were lower where there was canal competition. Messrs. Fellows, Morton, & Co., the great canal carriers, stated at the meeting held at Nottingham that if they had a 6 feet deep waterway from Nottingham to the Humber they could carry goods over that route for 4s. per ton, against the present rate of 8s. to 10s. per ton, according to the classification. He thought that all canals, in order to compete with the railways, should be controlled by some public trust, he did not think that the cost of conveyance of coal on the Aire and Calder navigation (one of the most successful of canal enterprises) was much lower than on the neighbouring railways.

Mr. H. C. PEAKE (Walsall) said that he had been sending coal by canal and by rail for twenty-five years between Cannock Chase and Birmingham, a distance of about 20 miles. The cost of haulage alone was about 1s. per ton. The canal over which the coal was conveyed was practically owned by the London and North Western Railway Company, and had not been improved for the last fifty years. There were the same small locks, necessitating the use of narrow barges, the same flights of locks, and the same heavy expenditure. Some two or three years ago, the canal company had a project for making inclined planes, which would have considerably reduced the cost of working; but it was withdrawn after being advertized, before it reached the Houses of Parliament. Possibly the new scheme would have reduced the rates from 1s. to 7d. or 8d. per ton; and, if steam-haulage had been applied, possibly the cost to Birmingham would not have exceeded 6d., or even 5d., equivalent to ¼d. per ton per mile. Some years ago he tried to work a steam-tug on the Birmingham canal from Walsall Wood to Wolverhampton, a length of 16 miles. The haulage cost 8d. per ton with horses; he worked the steam-tug for some twelve or eighteen months at a cost of about 4d. a ton. The writer of one of the papers hit the nail on the head when he said that public opinion was not ripe for steam-haulage. He had no help in his experiments with the steam-tug, everyone was against him. Nevertheless, he believed that a steam-tug could be built for £250, and it would draw five barges containing 150 tons of coal at a speed, regulated by the wash of the boats in a narrow canal, of 2½ to 2¾ miles per hour—the same rate as a horse. There was no competition between canal and rail in the Birmingham district until January of this year. The cost of conveying a barge into Birmingham from the Cannock Chase district, including boat hire, was 2s. 9d. to 3s. per long ton of 2,400 lbs., against 1s. 6d. per ton by rail, with 6d. for the truck in addition, or altogether 2s. per ton. If the improvements he had mentioned with regard to the inclined planes and steam-haulage were carried out the canal would then be able to compete on equal terms with the railway.

Mr. SPENCER (Leicester) said that if any colliery had been dependent upon a canal during the last month or two, it would be in a very poor way. Just when they wanted the canal to take the coal away it would be frozen up. In this climate a great many weeks would have been lost at the time when people most wanted coal.

Mr. S. LLOYD (Birmingham) said that in Birmingham and in South Staffordshire generally they felt the heavy rates, particularly so because the only available canal-routes to the sea, except the Severn route, were

in the hands of the railway. During the weather of the past month, it had been impossible to tow barges by horse-power, as, with a few nights' frost, the canals became frozen over and useless. This all pointed to the necessity of steam-haulage on the canals. If steam power were employed in the barges, they would break up the ice continually into fragments, and in ordinary seasons when there was continuous daily traffic such canals would be open all the year round.

Mr. Collier (Manchester) said that he could give his experience of the Bridgewater canal of which he was manager, and which was one of the busiest canals in England. On this canal, which was for 30 miles without any locks, there were twenty-six steam-tugs engaged, but in the present frost they were entirely overpowered, and the ice was many inches thick and quite impassable. The principal question raised by Mr. Wells was the moving of Government to take over the canals. Comparisons with what was done in other countries would, however, not be fair arguments, as there were great physical differences. England was a comparatively small country with a very large seaboard, and consequently coasting transit largely superseded canal conveyance between seaports. On the continent of Europe there were large areas of almost level surfaces where canals were easy to construct and cheap to maintain, where only railway transit was in competition, and the large watersheds afforded water supplies which in England were not obtainable. It was necessary to bear in mind all these things which made Mr. Wells's and other speakers' figures unreliable as guides and fallacious when used in comparison. Farther, the American and European statistics were based on long-leads, in some cases hundreds of miles, and over waters free from toll and not artificially constructed. Such data would be of no use to compare with the short-leads possible in England. As to steam-haulage, the speaker pointed out that this was available to-day, and the canal companies were only allowed to charge when the power was in a boat not carrying cargo, and even then was subject to the authority of a nominee of the Board of Trade as to the amount.

Lord Francis Hervey (London) wrote that the only remarks which he would venture to make, related exclusively to the inland waterways in connexion with the ports of King's Lynn and Wisbech, and were as follow:—(1) The councils of the counties interested should take the place of the too numerous and inaccessible bodies at present controlling the navigations, with facilities for joint action, so as to preclude the mischief of inharmonious administration. (2) The county councils should have the power of buying up and extinguishing the rights of toll. (3)

The direct water-route between Peterborough and Wisbech should be made effectively available for traffic; and (4) The navigations should be improved.

Mr. John T. Brunner, M.P. (Northwich) wrote that it had been a great pleasure to him to read Mr. Wells' paper, bringing together in so admirable a fashion the results of long experience, and he did not remember ever to have read a paper more full of eloquent facts. It should (he thought), especially if backed by such a resolution as Mr. Wells had suggested for adoption by the meeting, have considerable influence upon the course of legislation. He trusted that the resolution would be adopted, and would be sent to Mr. Bryce, the President of the Board of Trade. He had already discussed with Mr. Bryce the desirability of applying to the making of canals the proposed legislation for facilitating the making of light railways, and although that Minister was not prepared at the moment to go farther than saying that a very interesting question had been raised; he (Mr. Brunner) was convinced that Mr. Bryce would receive the resolution with a considerable amount of sympathy. No one could, it appeared to him, follow Mr. Wells' arguments and study his figures, without coming to the conclusion that the making of canals, the improvement of existing canals, the amalgamation of existing canal companies, and the acquisition by independent companies of canals now owned or controlled by railway companies, was of infinitely greater and more urgent importance to agriculturists and other traders than the making of light railways.

Mr. Wells, in reply to the discussion, said that he would take the questions in the order in which they had been asked. Steam-lighters had been at work on the Weaver navigation for some thirty years. The locks, built of late years, were large ones, 230 feet long by 42½ feet wide. The boats which had been constructed hitherto carried about 350 tons as a maximum, and the cargo was taken along the Weaver navigation and Mersey estuary to Liverpool. Steam-lighters were also used for towing three other lighters, sometimes more, but usually three, and the locks could take them all in at once, and thus something like 1,000 tons was lowered or raised from one level to another. The size of the canals was a matter of very great importance, as it not only fixed the size of the vessels, but to a very great extent it regulated the speed at which they might navigate. The speed on the Weaver was regulated by the cargo, no restrictions being imposed. A steam-lighter, the cargo of which was wanted in Liverpool in haste, went singly at the rate of 4 to 5 miles per hour; and every barge that was added to her load diminished the speed.

The most economical way of working was to take ample cargo, and, as far as he could judge, the custom of the carriers was to load as deep and build as large a vessel as circumstances allowed. When he took charge of the Weaver navigation the draught of water was 7 feet 10 inches, but when he left, the draught was 10 feet. The shorter locks were removed, so that about 5 feet could be added to the length of the vessels throughout the navigation. He found that the salt-owners, as the dimensions of the locks permitted, not only built larger boats, but raised and lengthened the old ones. That was practical experience of what was worth doing to obtain economy in transportation. The cheapness of steam-haulage was dependent in a great measure on the tonnage. A horse would tow a small cargo almost as cheaply as a steam-boat. But with trains of boats, steam-haulage undoubtedly was the cheapest. He was certain, although traffic on canals may have increased somewhat during the last ten years, that it bore no comparison with the increased traffic on railways. Practically, canal traffic stagnated while railway traffic increased rapidly. On the contrary, in France and Germany, year after year water traffic was relatively increasing in greater proportion than railway traffic. Some remarks had been made as to the difficulty of treating coal-traffic economically by water, because of the frequent changes and breakages and so forth. Messrs. Cory & Sons, London, had built lighters to carry 350 tons, these were loaded in the Trent and towed to London, the same collier taking in tow one, two, or three of these lighters, according to the season of the year, and the cargo was delivered in the docks at London, above or below bridge. It is intended that these lighters shall trade on the Aire and Calder navigation; they can traverse many miles, but cannot reach any colliery at present. There are one or two bridges which have to be altered, as the lighters stand about 13½ feet out of the water when light. As soon as the alterations contemplated have been made, these lighters will be able to load from six collieries in the West Yorkshire district. The coal will be tipped direct from the tubs used in the mines, and taken to London without farther transhipment. This means of transport had now been in use for four months (the worst months of the year) and might be considered to be established, Messrs. Cory & Sons being quite satisfied with the experiment. The lighters could be taken to the collieries in the South Yorkshire coal-field if the Sheffield navigation were improved at the lower end, and this need not involve an excessive outlay. The compulsory purchase of canals by the Government was not advocated by the speaker, and his present attitude towards

the matter was one of enquiry. Canal navigation demanded very careful consideration in this country, especially when we found that continental nations were willing to spend large sums of money on improving their waterways. He had lately been in Germany and found that salt-mines (in the centre of Germany, having water-communication with Holland, Belgium, and Hamburg) had shut out English salt from Holland and Belgium to a great extent, and were actually sending salt to Newcastle-upon-Tyne (being transhipped at Hamburg). This latter competition was rendered possible, owing to the very cheap carriage down the river Elbe and by sea. He did not find that the German salt-miners worked longer hours or were paid lower wages than our miners. He was told that they commenced to work at 6 a.m., had half-an-hour for their meals, and came out of the mine at 2·30 p.m. That was exactly the same time as salt-miners worked in Cheshire. He also understood that they earned within a fraction the same wages as were paid in Cheshire. One could imagine, for train-loads of coal from Wigan to London, that larger trucks would be an advantage. It must be recollected that English railways had been made to accommodate the existing truck, and if larger trucks were adopted, the probability was that their wheel-bases would be larger and the curves would not be so readily negotiated as they were by the present description of waggon. He did not think that a great reduction of value of railway property should be feared if inland navigations were improved. Traffic led to traffic, and facility for traffic bred traffic. So far as railways in America were concerned those were the first to adopt improvements and a low transport rate which ran in competition with the grand system of navigation from the Western lakes to the Atlantic seaboard. The Erie canal had been a great factor in the making of New York, and unless that canal had been in existence the port of New York would not have gained its present commercial position. It had also been shown that the improvement of the Rhine navigation had not been destructive of the railway traffic along its banks. Some members talked of the possibility of reducing railway rates to 0·25d. per ton per mile. That, of course, was a very great reduction on existing rates, but the traffic from Chicago to New York was carried by water for 0·10d. per ton per mile. An authority said that the Americans had cut their railway rates down to 0·40d. per ton per mile, but the same authority which gave 0·40d. for railway rates gave 0·20d. for rates by water. The question of canals being frozen, and therefore forming unsatisfactory means of transport, was one which might be expected to be raised at this season, but he should like to

remind members that the canal which carried most traffic (more than the Suez Canal) was open on an average for 220 days per annum. In 1892, it carried 11,000,000 tons in 230 days, and until recently only one lock was provided. He referred to the Sault St. Marie canal. He therefore did not think that the fact that canals were closed for a certain number of days by frost, although it was a great detriment and hardship to many people, was a valid reason for saying that canals were unworthy of trust or unworthy of being improved and used. The secretary had read a letter from Mr. Brunner, M.P., chairman of Messrs. Brunner, Mond, & Co., who was fully conversant with the business of his firm. The works at Northwich alone receive upwards of 400,000 tons of coal, limestone, and other materials per annum, and the company have other works on the Trent and Mersey canal, Leeds and Liverpool canal, and also on the river Thames. Mr. Brunner was very strongly in favour of a resolution being taken from this meeting, but the President had ruled that to be out of order. What appeared to him (Mr. Wells) to be open in the matter of inland navigation was this:—The Government under a certain amount of pressure were prepared to bring in a bill to give facilities for making light railways. If any persons who were interested in canals had suggested such a thing on their behalf, no doubt the railway interest would have been exerted to prevent anything of the sort from taking place. It appeared to him that when the bill was before the House, and it was seen that there were provisions introduced into it by which land could be acquired more readily and expensive forms avoided, if some member would move that the bill should include canals, then we should possibly find there was no real reason why canals should not reap the benefit, and canals would undoubtedly be included. He hoped that might be so. Mr. Collier referred to the comparison of rates here and abroad as not altogether fair. He thought that Mr. Collier's criticisms were perfectly fair. If a parcel was carried a few miles and several canals were passed over, the charge would be more per mile than if carried for a longer distance or by one company. He (Mr. Wells) wanted to see the mileage of canals increased under one management. When this was done, it would be found that canal traffic could be worked at a less rate than it was at present. The advantage of large canals over small ones was shown thus:—the Bridgewater, the best of the shallow barge-canals, well worked and managed, only took about one-third of the coal from the Bridgewater collieries, two-thirds being carried by rail. The Weaver navigation, when he (Mr. Wells) was connected with it, took two-thirds of

the output of the salt-works and left one-third for the railways. That seemed to him to point to the advantage of a large canal as compared with one of less capacity. What he would have liked if the Institution could have seen its way to do so, was that a resolution should be passed asking the President of the Board of Trade to call for returns supplementary or somewhat similar to the return made in 1888; but in the light of the information which had been gathered since then on the subject. That return was essentially incorrect in many points, and did not go far enough. At present, personal knowledge was the only trustworthy guide. He need not call attention to the errors of commission and omission. They were palpable to any one referring to a canal he was intimately acquainted with. The authorities at the Board of Trade appeared to have entered in the Blue Book, without any question or criticism, whatever information was sent to them. Certain canals had given correct information so far as they had been asked for it, others had not. There are many canals on which the locks varied in size, and in which the depth of the water varied. There was no indication in the Blue Book in many cases as to this variation. Anyone attempting to work from it would inevitably be misled. The returns under the head of maintenance of works and management were also comparatively useless: the questions, he thought, could not have been put sufficiently clear; at any rate any answer which was received seems to have been entered, so that on the Lancaster canal it is said to have cost £49 per mile, and on the Shropshire Union £539 per mile for a similar service. No useful information could be gathered from such returns. There was no reference to the headway under bridges. This was a very important point. Mr. Jeans alluded to the inability of canals to compete with railways in density of traffic. He (Mr. Wells) could not understand the paragraph. The canal was not merely a thoroughfare, but also a siding. The more crowded the banks were with wharves and factories the better, so long as the waterway was sufficiently wide to allow for traffic passing while vessels lay at the wharves. Priestley's map referred to by Mr. Saner was well known to the writer. It was, he supposed, sixty years old. Not only were derelict canals shown by the same colour as those in use, but many canals which were never constructed were also shown in a similar manner. Mr. Peake's experience and statements of the cost of transport by canals in the Midlands was most valuable testimony in favour of amendment. To possess canals which could not or did not compete with railways was an anachronism, and ought not to be tolerated any longer. No doubt there was a Railway and Canal

Commission, but owing to the cost of presenting a case and the proverbial uncertainty of law it was seldom invoked. A readier means of securing the object sought was imperatively demanded.

Sir E. Leader Williams (Altrincham, Cheshire) wrote that the question of the future of the canal system of England was a most important one for the trade of the country. It was at one time thought that the introduction of railways rendered canals of comparatively little use, and the owners of the canals were glad to dispose of their property, in many cases, to the railway companies, who were equally willing to become purchasers in order to reduce competition, and also, in some instances, to facilitate the construction of their lines. The result had been to block the progress and improvement of canals at home, while abroad the full development of waterways had advanced rapidly, without unduly interfering with the construction of railways. The experience of other countries proved that both were advantageous to the development of trade, as canals could deal with certain classes of traffic more cheaply than railways, which must always have an advantage where speed of delivery was necessary. As traffic increased, the railway companies had largely increased their capital expenditure, with little if any advantage to their shareholders. The necessity of mixing up fast passenger traffic with slow goods and mineral trains had compelled the railway companies to double large portions of their main lines and to increase their siding accommodation. If canals had been improved at the same time that railways were being constructed trade generally would have benefited by lower rates of carriage, and this would not have injuriously affected railways, whose capital expenditure would have been less, while they would have had their share of the advantage of the improved trade that would result from reduced charges on heavy goods and minerals. The question now to be considered was, how to place canals on a proper footing. The cost of improving them must be large, and it was only by enlarging the main lines of narrow canals and giving increased depth, on an uniform system, that any real advantage would be gained. Once constructed, a proper barge-canal had great advantages over railways. Fast or slow traffic could pass at any point, and as there was no renewal of permanent way, the cost of maintenance was small, and remained almost stationary, even if the traffic largely increased. Taking Birmingham as a centre, no one could doubt that the improvement of the canals that connected the Midland district with the rivers Mersey, Humber, Thames, and Severn would be of great advantage, but it was doubtful, without the aid of Government,

whether the capital necessary could be found for even one of these improved lines of communication with the sea. Yet it was a point to be considered, looking at the necessity for reducing the cost of carriage, in order to better enable us to compete with other countries who had already constructed large barge-canals at the public cost. And seeing that the expenditure would be entirely at home, giving employment to home labour, it was a question whether it would not be advantageous to the country (now that capital could be raised at a low rate of interest on Government securities) to bring the numerous smaller canals into one public trust, with the object of bringing them uniformly up to date, so that they might again take their place as important agencies for the development of trade and commerce.

Mr. J. A. Saner (Northwich) wrote in reply to the discussion that he thought Mr. Hunter had not fully grasped the object of his paper. He was quite in accord with the opinion that, when possible, coasting traffic should be provided for, but the dimensions laid down in the writer's paper were for purely artificial canals, such as the proposed Weaver-Birmingham canal, running through thickly populated districts, and encountering innumerable obstructions, such as railways, roads, scarcity of water, etc. It was in such cases, which would be in the majority, that he was of opinion that his standard dimensions, allowing for barges of 300 tons burthen, would be the largest practicable. He hoped within measurable time to see coasting steamers of 500 tons at Winsford on the Weaver, and was of opinion that all rivers of a similar calibre should be, if possible, made available for such craft. He thought if the experiment, mentioned by Mr. Wells, which was being tried by Messrs. Cory & Sons, of towing 350 tons lighters from the Trent to London, was a success, that there would be no reason why the same lighters could not traverse such a canal as he had suggested with the greatest ease, and amply provide for the trade which Mr. Hunter, in conjunction with all other engineers who had studied the subject, wished to see accommodated. Mr. S. Lloyd, of Birmingham, was right in conjecturing that if steam power were used on canals that they could be kept open in winter. The use of steam-tugs alone would not be sufficient, unless provision were made for clearing away the ice after it had been broken, as after several consecutive nights of severe frost the broken pieces congeal together and become so tough that even steam is of no avail, and although the pieces may be kept apart, the risk of damage to the steamers' propellers was anything but a theoretical risk. He had managed, by dint of most strenuous exertions, to keep the river Weaver open for traffic during

the whole of the recent frost (six weeks), although the ice in unbroken places attained a thickness of 8 to 9 inches; but this result had only been obtained by the constant running of steamers and the labour of large gangs of men who were employed in pushing the broken ice over the weirs. The weirs were specially provided with ice-caps, and the accumulations in the bye-passes below were in some cases 15 to 16 feet in thickness, and extended for from 100 to 300 feet in front of the apron of the weir. Although it might not be possible to keep open such a canal as he had suggested, for the whole duration of such a frost as had recently been experienced, yet with proper provisions, such as above described, he had little doubt that the stoppage would be only a day or two in duration, and nothing in comparison with the trouble now being experienced by the present small canals.

The PRESIDENT was of opinion that Mr. Wells and the other writers of papers had made out a very strong case in favour of the farther development of canals, and he believed that the balance of opinion of the members was to the same effect. He believed that the papers would prove a valuable addition to the *Transactions* of the Institution, and although the Institution might not be able to pass such a resolution as Mr. Wells had suggested, he thought that the discussion at that meeting would materially strengthen the hands of all persons interested in the more efficient working and management of canals.

Mr. EMERSON BAINBRIDGE (Sheffield) proposed that the thanks of the members be given to Mr. Wells and the authors of the other papers under discussion. He might not have been successful in having a resolution put forward from this Institution, but there would be no harm in those members who were connected with the Mining Association of Great Britain bringing it before that association.

Mr. G. J. BINNS (Netherseal) seconded, and the resolution was carried unanimously.

Mr. E. D. MARTEN read the following paper on "The Severn Navigation, with Particular Reference to Recent Improvements":—

THE SEVERN NAVIGATION, WITH PARTICULAR REFERENCE TO RECENT IMPROVEMENTS.

By E. D. MARTEN, M. Inst. C.E., Engineer to the Severn Commissioners.

The river Severn may be regarded as consisting of four distinct sections. First, there is the uncanalized river from its source in the Welsh hills to Stourport. A portion of this, from the Shropshire coal-field downwards, is navigable in the winter months, but it is now little used.

The second section is the canalized length of 42 miles from Stourport, through Worcester to Gloucester. It is this section which forms the subject of the present paper.

The third is the tidal estuary from Gloucester to Sharpness, which is so exceedingly tortuous and so choked with shifting sands that more than one hundred years ago all attempts to use it as a waterway for sea-going vessels were abandoned, and the Gloucester and Berkeley ship-canal commencing in the canalized portion of the river at Gloucester, and terminating by a junction with the river again at Sharpness, was constructed. This ship-canal is 16 miles in length, as compared with about 26 along the river-course which it has superseded, and it allows of the passage to Gloucester of vessels of about 600 tons burthen.

Finally, there is that section of the river from Sharpness to the Bristol Channel which is practically an arm of the sea.

At Stourport, where, as above stated, the canalized portion of the river commences, the Staffordshire and Worcestershire canal enters, and at Worcester, some 12 miles lower down the river, the Worcester and Birmingham canal comes in. Both of these canals are connected with the ramified canal-system of Birmingham and the Staffordshire Black Country, which at Stourbridge is only 14 miles distant from the Severn at Stourport, whilst from the city of Birmingham to Worcester it is 30 miles by canal. By means of these two canals the Severn is connected with the Mersey and the whole of the canal-system of the North of England, including the Manchester ship-canal.

Traffic is conducted along them by means of the ordinary canal-boat of 7 feet beam and carrying from 25 to 35 tons, and on reaching the Severn one of two courses is adopted with respect to it. If it be intended to be shipped from Gloucester, no transhipment occurs, as the canal-boats proceed down the river and tranship over the ship's side at Gloucester. If on the other hand the traffic is intended to be delivered at or shipped from Bristol or other Channel ports, it is, on reaching the Severn, transhipped into a class of vessel known as a "trow," the carrying capacity of which is from 80 to 100 tons, and which is sufficiently seaworthy to face the rough weather sometimes met with in the Severn estuary below Sharpness. Import traffic is conducted on much the same lines.

The haulage is for the most part effected by means of steam-tugs and is conducted in fleets or trains, as many as twenty-seven boats having at times been drawn by a single tug.

The navigation is divided by means of the locks and weirs into six pounds, from the lowest of which the Gloucester and Berkeley ship-canal locks up, and it is at one level for the whole 16 miles, at the end of which it locks down again into the Severn estuary.

The three locks above Worcester admit of the passage of a vessel about 85 feet long by 15½ feet beam and drawing 6 feet of water.

The two locks below Worcester, however, namely, the Diglis lock near that city and the Upper Lode lock at Tewkesbury, are of sufficient size to admit of the passage through them of vessels which, if built on the ordinary lines, might have a length of 135 feet, a beam of 22 feet, and a draught, when the river was at dead low summer-level, of 9 feet; in other words a sea-going steamer capable of carrying, in addition to her machinery, some 300 tons of cargo.

Until recently, however, it has not been possible to derive any advantage from these large-sized locks for two reasons.

Firstly, because the lock from the river into the Gloucester and Berkeley ship-canal, although long enough and wide enough for a vessel such as that above-named, would only admit of the passage of a vessel drawing about 7 feet 8 inches.

Secondly, because the channel of the river between Worcester and Gloucester, although of ample depth and width for about 18 miles out of 30 miles, the distance between those two cities, was blocked for the remaining 12 miles by certain shoals which restricted the draught of vessels using the river to 6 feet at low summer-level. These shoals were not confined to one particular length of 12 miles of the river, but were scattered about, some being near Gloucester, others near Worcester, and the remainder at intermediate points.

In the year 1889, these facts having been brought under the notice of the Severn Commissioners (who are the authority responsible for maintaining the navigation of the 42 miles of river between Stourport and Gloucester) by the writer's late father, Mr. Henry J. Marten, who was then their engineer; he was instructed to make a new survey of the bed of the river and report to the Commissioners as to the cost of dredging a channel, with a minimum depth at low summer-level of 7 feet from Stourport to Worcester Bridge, and of 10 feet between Worcester Bridge and Gloucester, so as to enable vessels to take full advantage of the size of the locks below and above that point. The channel so cut to have a bottom width of 40 feet in both cases.

He accordingly reported on August 24th, 1889, to the effect that the cost of dredging the channel to a depth of 7 feet everywhere above Worcester Bridge would be £1,702 17s. 8d., and the cost of dredging the 10 feet channel below Worcester Bridge £12,227 18s.

Acting upon this report, the Severn Commissioners went to Parliament, and in 1890 obtained an Act empowering them to raise £30,000 and to expend it on the following works:—

(1) The making of certain structural alterations in the shape of the bottoms of the three locks above Worcester Bridge, so as to admit of the passage of square-sided vessels measuring 15 feet 6 inches in their widest part and drawing 6 feet when loaded.

(2) The deepening of the channel as aforesaid to a minimum depth of 7 feet above Worcester Bridge.

(3) The deepening of the channel between Worcester Bridge and Gloucester to a minimum depth of 10 feet at low summer-level.

(4) The deepening of the entrance-lock to the Gloucester and Berkeley canal, so as to admit of the passage through it of vessels drawing 9½ feet.

(5) The construction of a transhipping-dock at Worcester with a depth of 10 feet, including the purchase of about 30 acres of land.

These works were commenced on July 2nd, 1891, and were completed on June 30th, 1894. They were designed, and for the most part carried out by the writer's late father, Mr. Henry John Marten, but on his death at the end of 1892, their completion was entrusted by the Commissioners to the writer.

The writer is pleased to say that they were carried out well within the estimates, so that notwithstanding the fact that certain extra items of expenditure, not included in the original estimates, were imposed upon the Commissioners during the passage of the Bill through Parliament,

and notwithstanding also that the cost of the Act itself greatly exceeded the sum which was provided for it, there remained on the completion of the works a balance of some £200.

The engineering operations were, for the most part, of a simple character.

The transhipping-dock at Worcester is about an acre in extent, but the Commissioners have, as stated, acquired some 30 acres of the surrounding meadow-land, so that there is ample space for extensions as soon as the trade develops. The water in the dock rises and falls with the water in the river, and it is everywhere 10 feet deep at low summer-level. A concrete quay-wall 300 feet long has been built along one side of it, behind which a metalled quay-space, 150 feet wide and 9 inches above the level of the highest recorded flood, has been left.

The action of the Commissioners in constructing the quay-wall and quay, without also providing warehouses or shedding, or any appliances for landing goods, has been somewhat harshly criticized, but a little reflection makes it clear that they have exercised a wise discretion both in what they have done and in what they have left undone. In proof of this opinion, the writer may point out that the main necessity for a transhipping-dock in connexion with the improvement scheme was that there should be a suitable place where transhipping might be effected without its having to be done in the open river, to which there were many objections. For such a dock, however, no quay-wall or quay was necessary, nor was it contemplated in the earlier stages. As matters developed, however, the suggestion was made that a quay-wall would most certainly be required as the traffic increased, and that such quay-wall could be constructed much more cheaply while the excavation for the main basin was being done than would be the case at any time after the water had been let in. This view of the case appeared to be so reasonable that the Commissioners determined to include its construction in their scheme. It was impossible for them to go beyond this, however, for the simple reason that no information existed as to the class of merchandize that would be likely eventually to make use of the quay, and it is hardly necessary for the writer to point out in this paper that warehouses, shedding, and appliances and machinery for unloading vessels must vary considerably in design according to the goods to be dealt with. Any outlay in this direction, therefore, in the present imperfect state of information as to the nature of such goods, would probably result in unnecessary and wasteful outlay. There is ample land for storing timber, flints, china-clay, etc., and for the erection of warehouses and sheds.

The entrance to the dock is 40 feet wide, and is crossed by a swivel foot-bridge. The quay-wall and bridge-abutments were composed of 8 to 1 cement concrete faced with 5 to 1 cement concrete. Excellent gravel for the purpose was found in the excavation, and not a single brick was used on the work. The wall rests upon a firm foundation of hard marl-rock.

The dredging of the new channel was mainly in sand and gravel, and presented little difficulty, but there were exceptions to its generally easy nature. The most important of these consisted of two barriers of hard marl-rock, one at Bunns Hill Ford, near Worcester, extending along the river for ¼ mile, and the other at Wainlode Ford, about 7 miles above Gloucester, which was about ⅓ mile in length. The channel over these barriers was only 6 feet deep when the water was at summer-level, and that depth was only found for a width of about 20 feet. It will, therefore, be seen that in order to cut a channel 10 feet deep and 40 feet wide, a face of solid marl-rock of that width, and averaging from 5 to 6 feet in thickness, had to be broken up and removed.

In former times, attempts had been made to break up these rock-shoals by means of blasting, but that was found to cost about 5s. per cubic yard removed, and the writer's late father therefore determined to try the system which has been successfully adopted by Mr. Messent in dredging rock on the Tyne. This method consists in breaking up the rock by means of powerful wrought-iron claws with steel points attached to the bucket-chain of the dredger. In the Severn operations every alternate bucket on the dredger-chain was removed, and a pair of these claws substituted for it, and the dredger was then set to work at the face of the rock in the usual way. The claws broke the rock up, ploughing into it with irresistible force, and either they themselves or the remaining buckets brought it to the surface. The rock dredged was sometimes as hard as building-stone, and lumps as big as a large sheep have been landed, but it was unfortunately useless for any purpose, as it crumbled away in a few weeks when exposed to the air. After much careful and anxious experiment, it was found that the best and most durable description of link-pin to be used for rock dredging was one of manganese steel. Anybody who has had any practical experience of rock-dredging will understand how important it is to use a link-pin which is neither brittle nor soft. These requirements were exactly met by pins of manganese steel, the only others which were of any use for the purpose being some special wrought-iron pins made by Messrs. Horton & Son, of Darlaston.

The cost of dredging this rock, including coal, stores, labour, and disposal of dredged material, was about 2s. per cubic yard, but this price did not include anything for hire of plant, as the Commissioners did the work themselves, and used their own dredgers.

About 12,000 cubic yards of this hard marl-rock was dredged altogether, and it was mainly used in forming training-embankments at places where, owing to the abnormal width of the river, there was any tendency for silting to take place in the newly dredged deep channel, and such embankments have proved particularly useful for the purpose.

Prior to the commencement of the dredging operations predictions were not wanting that in some places the channels would silt up as quickly as they were dredged. It is found, however, that this is not the case, the only tendency to silting being at places where the river is curved and also of abnormal width, with the deep channel on the convex side. At such places the evil has always been overcome by means of these training-embankments.

The other works presented no features of particular interest.

Were it not for the fact, which the writer has already mentioned, that a depth of 10 feet or more existed for the greater part of the length prior to the commencement of the operations, it would be hard to realize that for the sum of £10,000, or thereabouts, the 30 miles of the Severn, from the port of Gloucester to the city of Worcester, has been converted from a mere barge-canal into a highway for sea-going steamers, capable of carrying 300 tons of cargo. In other words, that for this small sum Birmingham, Wolverhampton, and the South Staffordshire mining district generally, have practically been brought 30 miles nearer to the ship's side than they were prior to the carrying out of the operations which the writer has described. The fact, however, is established, the works are completed, and the river is ready to-day for the passage of a vessel of such build as the writer has described.

Owing to the existence at Gloucester, however, of the Westgate Bridge, which is a low stone-arched bridge, having a headway of only 18 feet at low summer-level, it is necessary that sea-going vessels for the Worcester trade shall be of somewhat different construction from those generally employed for sea-going purposes, but up to the present time no such vessels have been constructed. Indeed, the only advantage that has so far been taken of the improvements which have been made in the navigation is that certain grain-vessels coming from Cardiff now load down to their maximum draught of 7 feet 3 or 4 inches, whereas formerly they were restricted to a draught of 6 feet at low summer-level.

Considering the enormous benefits likely to accrue to Birmingham and the South Staffordshire Black Country from being brought, as above stated, 30 miles nearer to the ship's side than heretofore, it has been a matter of some surprise to the Severn Commissioners that no steps have been taken to reap the advantages to be derived from the facilities which they have provided; especially as the toll remains the same as (or indeed, as the result of recent legislation, somewhat less than) it was prior to the construction of the improvement-works. The funds for carrying out the works were lent to the Commissioners on mortgage by various corporations and other interested persons, the interest to be payable out of any increase that may arise in the income from increased traffic resulting from the improvements, but neither interest nor principal can be recovered except from that source.

It having been suggested that the delay in constructing suitable steamers arose either from a general want of knowledge with respect to the existing depth of the Severn, or from some uncertainty in the minds of traders as to whether it were possible to build sea-going steamers of the class which should be capable of navigating under the Westgate Bridge at Gloucester, the Severn Commissioners have recently been taking such steps as lay in their power to get together information upon the matter, and give it the fullest publicity.

Amongst other things it came to their knowledge that improvements very similar to those on the Severn have recently been carried out on the Seine from the port of Rouen up to Paris, and that notwithstanding the existence of certain bridges very nearly as awkward as the Westgate Bridge, sea-going vessels were trading between the ports of Liverpool and London and the city of Paris. Consequently they instructed the writer in October last to obtain what information he could with respect to the navigation of the Seine, and report to them thereon. The writer accordingly visited Paris during October and reported to the Commissioners on December 18th, 1894, and this report has by their orders been printed and widely circulated.

As stated in that report, the writer found that three sea-going steamers whose tonnage varied from 140 to 500 were trading from English ports to Paris. Two of these, belonging to Messrs Burnett, of London, had been regularly trading for the past ten years, whilst the third was a new venture trading from Liverpool.

The writer also found that the navigable depth of the Seine was 10 feet 5 inches as compared with 10 feet, the present navigable depth of the Severn.

On the Seine, there are three bridges, under all of which the sea-going steamers have to pass, the headway of which is but little in excess of that of the Westgate Bridge at Gloucester. It will be seen from Fig. 1, that one of these, the bridge of Sèvres, although nominally

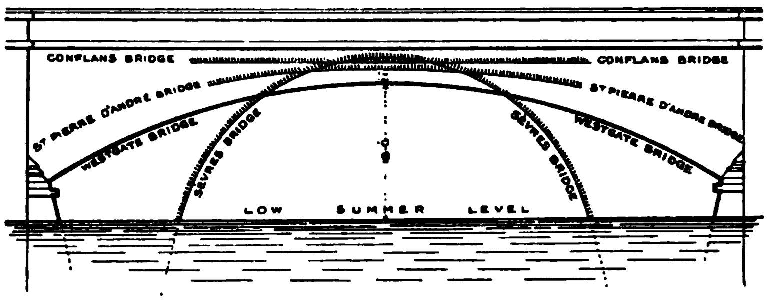


Fig. 1.—Westgate Bridge, Gloucester, showing the Comparative Outlines of the three worst Bridges on the River Seine.
Scale, 26 feet to 1 inch.

having a headway 4 feet greater than the Westgate bridge, is constructed with so narrow and pointed an arch that for the purposes of navigation it is hardly any better than that bridge. Mr. Rabel, the engineer-in-chief of the portion of the Seine where this bridge is situate, informed the writer that in times of high water it was a bar to traffic, and on that account it would shortly be reconstructed. As a general rule however it in no way blocked the sea-going vessels. Its case is therefore in every way analogous to that of the Westgate Bridge, which the Commissioners intend to alter whenever they may be provided with funds for the purpose, as it not only blocks sea-going steamers, unless of special construction, but it also blocks all traffic in times of flood. It is unnecessary, however, for the Midland districts to wait for this—at present—somewhat indefinite date, when the advantages to be derived from what has already been done may be reaped immediately by a small and remunerative outlay. The headways of the other two Seine bridges referred to are 2 feet and 2 feet 6 inches respectively greater than that of the Westgate Bridge.

The locks on the Seine are longer than those on the Severn, and consequently it is possible to build steamers to navigate to Paris with 500 tons on board, whilst the Severn steamers would be restricted to 300 tons. This, however, would be a very paying size, as is shown by the fact that one of the Seine steamers carries only 140 tons and has been running between London and Paris for ten years.

At the present time, goods going by water from the Birmingham district to Continental ports are carried in narrow canal-boats, through Worcester to Gloucester, a total distance of 60 miles, and there they are transhipped into the sea-going steamer. This often has no greater carrying capacity than the vessels which the writer proposes for the Worcester trade, but which, not being of special construction, are barred by the Westgate Bridge.

It is quite certain that the cost of transport must be greatly reduced when half of this 60 miles journey is made in one bottom instead of ten or twelve, as would be the case if the transhipment took place at Worcester instead of Gloucester.

What the writer saw on the Seine convinced him that it was feasible to construct sea-going vessels capable of navigating the Severn river up to Worcester. As an additional proof of this, he may mention that some thirty-five years ago two sea-going steamers named the "Ironside" and the "Cuirassier," carrying respectively 120 and 140 tons, were built and worked between Worcester and the French and Irish ports. The length of these vessels was 94 feet, their breadth 19½ feet, and their draught 7 feet. Unfortunately, like a great many other good things, these vessels were a little before their time, as the weirs at Gloucester were not constructed at that date, and the consequence was that in summer time the water in the river between Gloucester and Tewkesbury, a distance of 13 miles, used to fall to so low a level that these comparatively deep-draughted vessels had to give up the Worcester trade. They continued, however, to trade between Gloucester and Irish and Continental ports for many years, and the writer has been told that the old "Cuirassier" is still at work on the East Coast.

A design for a steamer to comply with the existing conditions of the Severn navigation in all particulars, and to carry 290 tons, with a 9 feet draught, has been submitted to the writer by a firm of Glasgow shipbuilders, who undertake to build and fit such steamers out complete with machinery of sufficient power to drive them when at sea and loaded, at the rate of nine knots (say, 10¼ miles) per hour, for the sum of £5,600 each; and the writer has no doubt that if there were a prospect of much business being done that the shipbuilders would be prepared to make a considerable reduction from that amount.

Such vessels would trade with Ireland and the Continental ports, to say nothing of the large coasting-trade which might be done with other ports in Great Britain.

As an instance of what is possible in this latter direction, the writer

may mention that at the present time copper is carried by two vessels called the "Jesmond" and the "Cheviot" from Newcastle-upon-Tyne to Gloucester, whence it is forwarded to Birmingham by canal, it being found cheaper to send by this circuitous route rather than direct by rail from Newcastle-upon-Tyne to Birmingham, although the distance by rail is only 210 miles, and the distance by sea and inland navigation exceeds 900 miles, 75 of which are over inland navigations. The "Jesmond" is only a very little too large to use the Severn navigation. If she could do so, the cost of carrying between Newcastle-upon-Tyne and Birmingham might be still farther reduced.

The writer mentions this case as one instance merely of the possibilities which exist for over-sea traffic from Worcester (within 30 miles of Birmingham) as a port, and many more occur to him, but this part of the question is more one for examination by a trading expert than by an engineer.

The writer's province, as engineer to the Severn Commissioners, is to make the public aware of the facilities which exist, and this he has endeavoured to do. It is for the public to avail themselves of those facilities or otherwise as they may feel disposed.

The Severn Commissioners have done all that their statutory powers permit them to do, they being much in the position of a highway board whose powers and duties extend only to keeping a good road. This they have done and are doing, and all they ask is that the trading public of Birmingham and South Staffordshire will come and make use of it. This, it will be admitted, is a modest request. There is no suggestion that a prolonged and costly Parliamentary struggle, such as Lancashire had to go through before it got power to make the Manchester ship-canal, shall be entered upon. No outlay of unknown millions has to be faced in the construction of the waterway. All that is done. Neither is there any uncertainty about the toll, as there is no power to increase it, and by Act of Parliament it is one of the lowest in the kingdom.

All that is required is for the traders to invest some £50,000 or £60,000 (a fraction only of what Lancashire spent in mere Parliamentary fighting) in what the writer believes would turn out to be an exceedingly sound and profitable enterprize, namely, the construction of a small fleet of over-sea steamers to trade from Worcester as a port. The writer says a small fleet advisedly, for he is of opinion that it would not long remain a small one, and that the investment would turn out to be so profitable, if well managed, that additions would be very soon made to the fleet. He commends the investment to the consideration of the trading

public in Birmingham and the Midlands as one from which they would probably earn a double profit, as, firstly, there would be the gain resulting from the reduction in the cost of carriage, and secondly, there would be the profit resulting from the carrying trade, which might still be handsome even after the rates were largely reduced.

The writer wishes it to be understood that he makes these suggestions without the least unfriendly feeling towards the existing carrying firms on the river, several of which have been established for very many years, and between whom and the Severn Commissioners and their officers excellent relations have always been maintained. Even if these firms did not themselves go into the over-sea trade the writer believes that they would reap a great advantage by its establishment, as all the over-sea traffic must be brought by ordinary canal-boat from the Birmingham and South Staffordshire districts to the ship's side at Worcester, so that whilst these carriers are not likely to lose a single ton of their existing trade they would probably get a large increase of business by this means.

Finally, while calling attention to the advantages which Midland traders may immediately derive from the Severn navigation in its present improved state, the writer is nevertheless anxious that the still greater advantages which would result from the conversion of the Westgate Bridge at Gloucester into an opening bridge, shall not be lost sight of. If this were done, any vessel, no matter how high out of water she stood, could pass through it if her dimensions did not otherwise exceed the capabilities of the navigation as previously described; and the writer is informed by a gentleman who subscribed largely to the fund for making the recent improvements, who is also a shipowner at Cardiff, and trades thence to the Midlands, that there already exist many sea-going vessels that would use the navigation under such circumstances, but which are now barred by the bridge. The cost of the suggested alteration is estimated at £11,250, but this does not include Parliamentary expenses and several other items, so that it is probable that powers to borrow £15,000 would have to be sought in any application to Parliament.

In addition to the Westgate Bridge, there are two other fixed bridges on the navigation between Gloucester and Worcester, but as each of these has a headway 7 feet higher than that of the Westgate Bridge, their case is not urgent. Until these are also converted into opening bridges, however, it cannot be said that the navigation of the Severn to Worcester is free to all ships that sail the seas.

The writer is of opinion that the day will come when, not only will all these improvements be carried out, but also the much greater one of

so deepening the river and enlarging the locks as to allow of those vessels of 600 tons which now navigate the ship-canal to Gloucester, proceeding to Worcester. Nature has already done two-thirds of the work necessary to bring about this result, so that the task which remains is comparatively a small one.

The Severn Commissioners, however, have no funds which they can apply to these purposes. They have always shown themselves willing to spend for the public good any funds entrusted to them with the view of improving the river, and the gratifying result has been that rates, both by rail and water, from Birmingham to the Bristol Channel ports, are considerably lower than in other directions.

The cost of future improvements must, like those in the past, be provided by the trading public interested in the matter, and it appears to the writer that it is for the Midland traders themselves to decide whether it is more to their interest to spend money in building sea-going steamers to use the navigation in its present state; or whether they prefer to provide the funds for altering the Westgate Bridge, and possibly for carrying out the other improvements which have been glanced at in the course of this paper; or whether, finally, as an alternative they are content to do nothing at all in the way of taking steps to mitigate the serious disadvantage at which they are placed in competition with others by reason of their inland situation.

Mr. L. F. Vernon-Harcourt read the following paper on "Inland Navigation, with Special Reference to the Birmingham District":—

INLAND NAVIGATION, WITH SPECIAL REFERENCE TO THE BIRMINGHAM DISTRICT.

By L. F. VERNON-HARCOURT, M.A., M. Inst. C.E.

Inland navigation has received much greater attention, and has been more largely developed on the Continent than in Great Britain during recent years, more particularly in France and Belgium. In France, as in England, the introduction of railways led to the neglect of inland navigation; but, after the lapse of about twenty years, interest in waterways revived in France, and considerable improvements in rivers, and extensions and enlargements of canals have been carried out.

Standard Dimensions for Inland Waterways in France.—When waterways came to be regarded in France as of national importance for the prosperity of the country, notwithstanding the large development of railways, the differences in the depth of the various canals, and in the sizes of the locks, were recognized as serious impediments to the due development of inland navigation. Accordingly, in 1879, the Government issued a decree that all the main lines of inland navigation in France should be given minimum uniform dimensions as follows:—Depth, 6½ feet; locks, 126½ feet long, 17 feet wide, and 6½ feet depth of water on the sills; and a minimum headway under bridges of 12½ feet. By thus obtaining a standard depth, and locks of uniform size, by works gradually carried out, vessels of 300 tons can pass along all the main lines of inland waterways in France; whilst along the Lower Seine, and a few of the waterways connected with it, converging to Paris, still larger vessels can be accommodated.

Development of Belgian Waterways.—Great interest has been manifested by the Government of Belgium in the improvement of its waterways. The Ghent-Terneuzen canal has been enlarged, a ship-canal to Bruges is about to be carried out, and various lines of water-communication have been formed, improved, or extended. The most interesting recent work, however, in relation to the subject of this paper, is the canal which will

place Mons in direct connexion by water with Brussels, Charleroi, and Liége, and by a junction with the Mons and Condé canal at Mons, will provide communication by water with the Scheldt, and thereby with the network of waterways intersecting the northern corner of France. This canal du Centre, 13 miles in length, and running in places alongside the Mons and Namur railway, forms a very important link in the waterways of the flourishing mineral districts of Belgium; and it has already been completed up to Thieu, a distance of about 9 miles from Mons, with a rise of 76 feet, accomplished by locks provided with side ponds to economize water.

Hydraulic Canal-lifts in Belgium and France.—The difficult part of the canal du Centre is comprised in the 4⅓ miles between Thieu and the junction of the canal at La Louvière with the Charleroi and Brussels canal, in which a rise of 217 feet has to be surmounted, and water is scarce. These impediments for a long time prevented this important line of communication in the coal-and-iron districts of Belgium from being undertaken. They are, however, being overcome by the erection of four large hydraulic canal-lifts, with counterbalancing caissons, like the lifts at Anderton on the Weaver, whereby vessels of 400 tons, floating in water, can be raised or lowered 50½ to 55½ feet in 2½ minutes, with an expenditure of only 270 cubic yards of water for each operation. One of these lifts was erected at La Louvière as a test of the system; and as it was proved to work satisfactorily, the three others are being constructed. A similar lift for raising vessels of 300 tons a height of 43 feet, was opened for traffic in 1888, at Fontinettes near St. Omer, on the Neuffossé canal, connecting the port of Dunkirk with the mineral districts of Belgium, owing to a flight of five locks having become quite inadequate to cope with the greatly increased traffic resulting from the enlargement of these waterways.

Locks with Large Rises, Deep Sills, and Cylindrical Sluice-gates.—Long delays at numerous locks offer a serious impediment to inland navigation, and greatly diminish the capacity of a waterway for the transit of vessels. The time, accordingly, occupied in the passage through locks has been greatly reduced within recent years in France, on altering the locks to conform with the standard dimensions: in the first place, by reducing the number of the locks and increasing their rise, which has the farther advantage of increasing the length of the reaches between the locks, and diminishing the fluctuation in their water-level due to lockings. This plan has been systematically carried out on the canal du Centre, the Scheldt-Maas canal, and the St. Denis canal; and on the latter canal, one

of the new locks, 205 feet long, 27 feet wide, and with 10½ feet depth of water on the sills, capable of admitting the largest vessels navigating the Lower Seine, has been given a rise of 32½ feet, four times the original rise of the locks, thereby enabling three locks to be suppressed.

In most cases also, in the reconstruction of the locks, the sills have been placed lower than required for the actual draught of the vessels, so that the entrance and exit of large vessels are facilitated by their immersed section not approximating too closely to the sectional area of the waterway in the lock. The outflow, moreover, of the surplus water displaced by a vessel on entering a lock, or the inflow on its leaving, is farther facilitated by numerous openings in the side-walls of the lock, communicating with longitudinal sluice-ways.

The filling also and emptying of the lock-chamber, in the process of locking, are much expedited by the longitudinal sluice-ways and side outlets, especially when the influx and efflux are controlled by large counterbalanced, cylindrical sluice-gates, like those adopted on the Weaver in 1878, which are very readily raised or lowered owing to the pressure being uniform all round them. For instance, the lock with the large rise of 32½ feet on the St. Denis canal, is filled or emptied in eight minutes; while the large lower lock-gate is opened or closed in one minute by hydraulic power, and the cylindrical sluice-gates are raised or lowered to their full extent in a few seconds.

Distribution of Traffic on French Waterways.—The uniformity in gauge of the main lines of French waterways has been so recently effected that the full advantage of this very important improvement has not had time to manifest itself; whilst several large connecting-lines are still in course of construction, and some modifications in existing lines have not yet been carried out. Accordingly, it is too early as yet to judge of the influence which the uniformity in the waterways may have upon the development of inland navigation in France, though more than 2,500 miles of rivers and canals have now the standard depth and size of locks, as compared with only 900 miles in 1878. In most cases, indeed, an improvement in traffic has already resulted from an improvement in the waterway; but it would be a most grievous error to assume that uniformity in size will ever lead to uniformity in traffic. A glance at the map published annually by the French Ministry of Public Works, in which the traffic on the several waterways is indicated by the width of a blue band along them, would at once dispel any such illusion. The main bulk of the traffic along inland waterways in France is confined to the Seine

between Montereau, above Paris, and Rouen (the limit of ocean-going navigation), and more especially to the northern waterways connecting the coal-fields and centres of iron industry in Belgium with Paris and Dunkirk.

Inland Waterways in England with a Large Traffic.—According to the Board of Trade returns for 1888, the Birmingham canal navigations convey by far the greatest tonnage of all the inland waterways of Great Britain, amounting to 7,713,000 tons in the year, more than two and a half times the traffic of the Bridgewater canals, with 2,917,000 tons. Next comes the Aire and Calder navigation, with its large coal traffic, carrying 2,211,000 tons; after which follows the Leeds and Liverpool canal, with a tonnage of 2,017,000 tons. The waterways which have a traffic of over one million tons a year are the Regent's canal with 1,673,000 tons, the Weaver navigation with 1,498,000 tons, the Forth and Clyde navigation with 1,257,000 tons, the Grand Junction canal with 1,172,000 tons, the Trent and Mersey navigation with 1,139,000 tons, and the Shropshire Union canals with 1,125,000 tons.* The most profitable of these undertakings is the Regent's canal, with a length of only 10¾ miles, and a net revenue of £4,228 per mile, owing to its exceptional position in the middle of London. The most remunerative, however, of the regular waterways of considerable length is the Aire and Calder navigation, 93 miles long, which yields a net yearly revenue of £1,213 per mile. The position of this undertaking, and its financial prosperity are undoubtedly due to the company having repeatedly improved its depth and increased the size of its locks, to meet the growth and requirements of traffic, which has enabled it to maintain a very profitable competition with railways in the carriage of bulky goods. The Bridgewater canals come next, with a length of 75⅓ miles, and a revenue of £895 per mile, serving important industrial districts of Cheshire and Lancashire; whilst the Weaver navigation follows after, with a length of only 20 miles, but with a revenue of £807 per mile, owing to its large traffic of salt from the salt-mines round Northwich; and then come the Birmingham canal navigations, nearly 159 miles in length, and yielding a net yearly income of £731 per mile, about double the return of the Grand Junction and Leeds and Liverpool canals, and still more in excess of the Trent and Mersey navigation. The above instances, and others that might be

* The proper basis of comparison of traffic along any route is the number of tons carried one mile, or the ton-mile; but, unfortunately, the Board of Trade returns, unlike the French returns, do not afford this information.

cited, such as the Rochdale canal and the Don navigation, show that a large traffic and good returns are obtained on those inland waterways of England which connect important industrial and mineral districts with seaports, where large quantities of bulky goods have to be conveyed, in spite of the serious hindrances which result from a want of uniformity in gauge in through routes, and the neglect shown in most cases to develop the capabilities of the waterways in accordance with modern requirements. Those waterways, indeed, have been most successful which, possessing a traffic in bulky goods, have been able, from their position, to secure uniformity of gauge from the districts they serve to the terminal seaport, and have also been improved in depth and size of locks to meet the growing exigencies of trade, such as the Aire and Calder navigation, the Weaver navigation, and the Bridgewater canals. The large traffic along the Birmingham canals, and the goods traffic along the Worcester and Birmingham, the Warwick and Birmingham, and the Warwick and Napton canals in proportion to their lengths, notwithstanding the small width of their locks, can only be attributed to the remarkable suitability of the goods for conveyance by water; and the accommodation and development of this traffic are deserving of far more consideration than has hitherto been paid to them.

Conditions favourable to the Improvement of Inland Waterways.—The foregoing particulars show that the traffic along waterways can be considerably expedited by the use of hydraulic lifts where the change of level is great, or by a smaller number of enlarged locks, with a large rise and improved appliances, where the slope of the ground is more moderate. It is also well known that a large traffic is conducted more economically and expeditiously along a large waterway. It has, moreover, been amply proved by statistics that those waterways attract the largest traffic which connect mineral districts with large towns and seaports, and that they are most prosperous when they possess uniformity of gauge, and are gradually improved to meet the growing requirements of navigation.

Birmingham, with its surrounding mineral districts, is manifestly peculiarly well-adapted for providing a large traffic along inland waterways connecting it with a seaport, for shipping its goods to foreign ports; for the inland waterways in communication with it have developed a large traffic, in spite of their inadequate size, their want of uniformity in gauge, and the diversity of their control. If the French Government considers that it is essential to continually improve the water-communication with the mineral districts of Belgium, and the Belgian Government con-

siders it expedient to construct a new canal, capable of accommodating vessels of 400 tons, under unfavourable physical conditions, in order to improve the communications of the mineral districts of Belgium, it is surely time for Birmingham to secure access to a seaport by a waterway capable of admitting vessels of a larger carrying capacity than 50 tons. British trade cannot be expected to maintain its supremacy for long if no effort is made to afford its inland industrial districts the same facilities for water-carriage as are readily provided by foreign governments for similarly situated centres of trade. Many of the inland waterways in England have succumbed to the competition of railways, partly owing to neglect of timely development, partly to the want of suitable traffic, and partly to the proximity of so many places to tidal rivers or the sea. Birmingham, however, is situated a long distance inland; and therefore its position, and the nature of its trade, mark it out as one of the chief districts in England which should long ago have obtained a commodious waterway to a seaport, with great advantage to its trade, and with financial benefits to the undertaking itself.

Position of Birmingham, and Possible Routes to the Sea.—Birmingham is situated in the basin of the Trent; but it is so near the boundary between this basin and that of the Severn, that it is at an elevation of about 350 to 450 feet above mean sea-level. Most large towns are situated so definitely within the valley of a river that their natural route to the sea is along that valley. The situation, however, of Birmingham in relation to the Trent, and its central position in England, afford it three or four possible routes by water to the sea. The natural fall of the land is by the valleys of the Cole and the Tame into the Trent; and it is also physically possible to obtain access from Birmingham by water to the Mersey, the Severn, the Thames, and by the Nene to the Wash; and, indeed, in a map (Plate XXV.) of the canals and navigable rivers of England,* a continuous waterway is indicated between Birmingham and all these rivers. Though the Trent valley at first sight appears to form the natural outlet for Birmingham by water, the existing route by which the Trent is reached is circuitous, passing along one of the Birmingham canals, part of the Coventry canal, and part of the Trent and Mersey canal, before reaching the Trent navigation near the confluence of the Derwent. The distance between Birmingham and Gainsborough by this route is 115 miles, or 136 miles to the Humber; the total variation in level is 461 feet, surmounted by 74

* *Map of Canals and Navigable Rivers of England and Wales.* By Mr. L. B. Wells.

locks; and the largest barge that can navigate the whole length is 71 feet long, 6 feet 10 inches broad, and drawing 2½ feet of water. The objections to this route appear to be the four different ownerships of the waterways traversed (two being controlled by railway companies), the totally inadequate width and depth of a great portion of this long route, and its divergence from the natural lines of Birmingham trade with foreign ports.

The route by the Nene to the Wash need not be taken into consideration, for the navigation of the river between its junction with the Grand Junction canal and Peterborough, appears to have fallen into decay; and if it is expedient to adopt this route as far as the Nene, it would be much better to continue along the Grand Junction canal to the Thames.

The three remaining routes, to the Mersey, the Thames, and the Severn respectively, are those for which schemes for an improved waterway between Birmingham and the sea have been proposed. In order to facilitate a comparison of these routes, both as regards the general variations in level, and the length of waterway to be improved or constructed, longitudinal sections are given of them, taken from published accounts of the three schemes, reduced to uniform scales (Plate XXVI.)*

The height of Birmingham above sea-level, and its distance by the nearest possible route from the point on any tidal river up to which ocean-going steamers can ascend, preclude the possibility of connecting it with the sea by means of a regular ship-canal, at any reasonable cost, even if the experience of the Manchester ship-canal had proved favourable financially to such undertakings. The rise to Birmingham, indeed, from sea-level is five times the rise to Manchester, and the distance of Birmingham from its nearest tidal port at Sharpness, on the Severn estuary, is more than double the distance of Manchester from Eastham. Accordingly no serious proposal has been made for constructing a ship-canal for ocean-going vessels to Birmingham, though two of the schemes for an improved waterway have received the ambitious, and somewhat misleading, title of ship-canal.

Birmingham to Liverpool by Water.—As Birmingham is near the southern part of the ridge which separates the basin of the Trent from that of the Severn, and this dividing-line runs for about 35 miles in a north-westerly direction before reaching the Mersey basin, any canal from Birmingham must skirt along near the high ground of this tortuous ridge,

* *Report on Improving the Water-communication between London and Birmingham.* By Mr. H. J. Marten, 1886; "The Birmingham and Gloucester Ship-canal," *The Engineer*, 1887 (1), page 499, and 1894 (1), page 471; "The Birmingham and Liverpool ship-canal," *The Engineer*, 1890 (2), page 247.

or in adopting a straighter course, must descend somewhat into the Trent or Severn valley before rising again to surmount the boundary of the Mersey basin. Accordingly, in adopting this route, a greater difference in level has to be overcome than the mere elevation of Birmingham above sea-level.

The existing route by water from Birmingham to the Mersey estuary, and thence to Liverpool, is by the Birmingham and Wolverhampton canal, past Wolverhampton, to the Staffordshire and Worcestershire canal at Autherley, of which only a very short portion is traversed before entering the Birmingham and Liverpool canal, which extends to Nantwich. From this town the route is continued along the Chester canal to Chester, and then by the Wirral line of the Ellesmere canal to Ellesmere Port, formerly on the Mersey estuary and now on the Manchester ship-canal. The waterways traversed after leaving the Staffordshire and Worcestershire canal, up to Ellesmere Port, form part of the system of the Shropshire Union canals, so that this route is owned by three independent companies. The total length of this route, between Birmingham and Ellesmere Port, is about 85 miles; and owing to a rise before reaching Wolverhampton, and a subsequent dip into the Severn valley before reaching the Mersey basin, the total variation in level reaches 585 feet, which is surmounted by eighty-five locks; and, moreover, two short tunnels are traversed. The largest barges that can navigate this route are 71½ feet long, 6¾ feet wide, and 3¼ feet draught.

The line for a canal from Birmingham to the Mersey, proposed in 1890 by the late Sir James Brunlees and Mr. McKerrow, only followed the above route approximately as far as Wolverhampton.* From this point it took a northerly direction, past Penkridge and Stafford, in the valley of the Penk, to Stone, where it entered the upper valley of the Trent, and continued to Stoke. Thence it turned in a north-westerly direction, and running approximately parallel to the Trent and Mersey canal, it passed Tunstall, then crossing from the Trent to the Mersey basin at Harecastle, it went on past Kidsgrove and Wheelock to Winsford, where, after a course of 63¾ miles, it was to join the Weaver navigation, 20 miles from the junction of this navigation with the Manchester ship-canal. The canal was designed to have a bottom width of 50 feet, for conveying vessels of 300 to 400 tons, it being proposed to effect the changes in level between the reaches by means of hydraulic lifts, similar to those of Fontinettes and La Louvière. The longitudinal section (Fig. 1, Plate XXVI.) shows that the canal was to commence at Birmingham, at a

* *Engineering*, 1890 (2), page 372, and *The Engineer*, 1890 (2), page 247.

height of 387 feet above mean sea-level, rising by two lifts to a summit-level of 472¾ feet about 3 miles short of Wolverhampton, and then descending by four lifts, between Wolverhampton and the crossing of Watling Street, into the valley of the Penk, to 296 feet above sea-level, which level was to be continued into the upper Trent valley, past Penkridge, Stafford, and Stone, to Trentham, for a length of 21 miles. Then it had to rise again by four lifts to another summit-level, 460 feet above the sea, in order to pass at Harecastle across the ridge between the Trent and Mersey basins, descending from this point by eight lifts to the Weaver at Winsford, 54½ feet above the sea. The total variation in level, accordingly, by this route would be 832 feet, proposed to be surmounted by eighteen lifts, with rises varying between 19¼ and 66½ feet, and averaging 46 feet.

This scheme would undoubtedly provide a waterway for Birmingham to the sea, quite on a level with the largest inland canals on the Continent; and the proposed system of lifts would enable the great changes of level to be rapidly accomplished with a small expenditure of water. This canal, however, would be a very costly work, being estimated by its promoters at £5,000,000. There was also some reference made in the description of the proposal, to possible settlement in the mining districts; but any settlement in the foundations of the hydraulic presses of the lifts would be fatal to their efficient working. Moreover, the tendency to such settlement is increased, in the case of the slightest instability of the foundations, by the repeated shocks to which the presses are exposed in the process of lifting the troughs. The scheme, moreover, by following the route of a portion of the Birmingham canals as far as Wolverhampton, would naturally be strongly opposed by the London and North-Western Railway Company which appears to control these canals, and also by the Shropshire Union Railway and Canal Company, whose traffic from the Birmingham canals to the Mersey it would tend to divert. The canal by passing through the district of the Potteries, would have the prospect of obtaining another class of goods traffic very suitable for waterways; but it would at the same time come into direct competition with the Trent and Mersey canal, and consequently with the North Staffordshire Railway Company, and might possibly be forced to buy up the Trent and Mersey canal, as the Manchester Ship-canal Company had to buy up the Bridgewater canal. Such an outlet for vessels of 300 to 400 tons from Birmingham to the sea, when once accomplished, would undoubtedly prove of great value to the trade of Birmingham; but the difficulties attending this route, and the very expensive character of the works through unfavourable country, seem to render it expedient to try and select some other route less certain to arouse serious opposition, and which might be obtained at a smaller cost.

Birmingham to London by Water.—When canals were being extended throughout England, it was natural that Birmingham should be connected by water with London. The configuration, however, of the intervening country is not favourable for such a waterway; for a portion of the Severn basin separates the Trent basin from the Thames basin, and the principal waterway between Birmingham and London crosses the basins of the Severn, the Nene, and the Ouse, before entering the Thames basin, involving considerable variations in level. By the Oxford canal, indeed, the waterway merely traverses the Severn basin in passing from the Trent basin to the Thames basin, and the river Thames is joined at Oxford; so that by this route the number of locks is less by one-third than by the Grand Junction canal; but this latter canal provides wider locks and a greater available depth, as well as a shorter course owing to the windings of the Thames.

The chief route, accordingly, from Birmingham to London by water, and the one which it has been proposed to improve, is along the Warwick and Birmingham canal to Warwick, then by the Warwick and Napton canal to Napton, where the Oxford canal is traversed for about 5 miles before reaching the Grand Junction canal which continues the waterway to its junction with the Thames at Brentford. The proposed improved longitudinal section of this route, between Birmingham and Brentford* (Fig. 2, Plate XXVI.), shows the considerable variations in level of the waterway in going across the basins of the Severn, the Nene, and the Ouse, whose water-partings are traversed in tunnels at Braunston and Blisworth, and in a cutting at Tring on the boundary of the Thames basin. The greatest dip occurs in crossing the valley of the Avon in the Severn basin, at a level of 180 feet above the sea; and the greatest elevation is attained at Tring, 393 feet above the sea, before descending finally to join the tidal Thames. The length of this waterway between Birmingham and Brentford, at the present time, is 135 miles; and the total variation in level along the route reaches 1,088 feet, which is surmounted by one hundred and sixty-one locks.†

The improvement of this route was recommended by the late Mr. H. J. Marten, in a report to a committee of the Birmingham Corporation, in 1886, which was approved by the committee.‡ At the present time

* *Report on Improving the Water-communication between London and Birmingham.* By Mr. H. J. Marten, 1886.

† *Returns made to the Board of Trade in respect of the Canals and Navigations in the United Kingdom for the Year* 1888.

‡ *Report on Improving the Water-communication between London and Birmingham.* By Mr. H. J. Marten, 1886.

only vessels 70 feet long, 7 feet wide, and 3¾ feet draught, carrying 30 tons, can pass through the locks of the Warwick and Birmingham and Warwick and Napton canals; and though the locks on the Grand Junction canal can accommodate vessels 70 feet long, 14 feet wide, and 4 feet draught, carrying 80 tons, the depth of the canal is inadequate to pass barges loaded with more than 50 tons. It was proposed to enlarge the waterway throughout to a bottom-width of 21 feet and a depth of 8 feet, and to make the locks 160 feet long, 14½ feet wide, and with a depth of 7 feet of water on the sills, so as to admit a tug-boat holding 60 tons of cargo at the same time as a barge of 80 tons, or a steamboat 120 feet long, 12 feet wide, and 6 feet draught, carrying 130 to 140 tons. The locks were to be reduced to ninety in number, and their rise increased in some cases to 27½ feet; and it was estimated that the time of transit would be reduced by twelve hours. The cost of the improvement-works was estimated at £1,250,000.

A good communication by water between Birmingham and London would be very advantageous, as, besides giving Birmingham access to the largest seaport of Great Britain, it would also promote the trade between Birmingham and the capital. The physical features of the country, however, are decidedly unfavourable for such a connexion; the route is very long; it would necessitate very extensive and costly improvements along the canals of four independent companies; and the great variations in level would render the working expensive, the passage of vessels relatively slower, and the expenditure of water very considerable for a large traffic. The widths proposed for the enlarged waterway, and for the locks, appear somewhat small, though the depth provided is ample; and it might be well to increase these widths to the standard dimensions of the main lines of waterways in France, and thereby provide for vessels of between 200 and 300 tons. Where the changes in level are abrupt, hydraulic lifts would economize both time and water. These suggested modifications would doubtless raise the cost, which, as proposed, is already considerable, considering the small increase in the tonnage of the vessels provided for; but it is essential in any scheme that provision should be made for vessels of the size suited to the requirements of inland navigation in the present day.

Birmingham to the Severn by Water.—As Birmingham is close to the south-western edge of the ridge separating the basins of the Trent and the Severn, it is possible to carry a waterway into the Severn basin in this direction by merely piercing the crest of the ridge by a tunnel, as effected by the Worcester and Birmingham canal, without any rise. The descent

from this ridge to the Severn is undoubtedly rapid; but there is some advantage in having the unavoidable descent from Birmingham to the sea somewhat concentrated, as by the adoption of lifts or inclined planes under such conditions, a considerable change in level between the reaches can be rapidly effected.

Birmingham is connected with the Severn at Worcester by the Worcester and Birmingham canal, from which town the Severn has recently been rendered navigable by vessels of 400 tons down to Gloucester; and thence, by the Gloucester and Berkeley canal, access is obtained to the Bristol Channel. The Worcester and Birmingham canal passes in a level reach from Birmingham to Tardebigge, a distance of 13½ miles, passing through four tunnels before commencing its descent of 425 feet to the Severn at Worcester, as shown by the longitudinal section of the existing canal (Fig. 3, Plate XXVI.). The first 217 feet of the descent are effected by a chain of twenty-nine locks at Tardebigge, followed by a chain of six locks at Stoke Prior descending 42 feet; and after a level reach of about a mile, a farther descent of 42 feet is accomplished by another chain of six locks at Dodderhill, which is separated from a third chain of six locks at Tibberton, by a level reach of about 5½ miles, passing through a very short tunnel. The remainder of the descent of 82 feet is effected by ten locks, making the total number of locks fifty-seven. The length of the canal is 30 miles; and barges 71½ feet long, 7 feet wide, and 4 feet draught, can pass along it.

The improvement of this canal to accommodate vessels of 200 to 250 tons was proposed by Mr. Keeling in 1887, by widening the canal at the top from 33 feet to 66 feet, and increasing its depth from 5½ feet to 9 feet, and by constructing thirteen locks, from 110 to 210 feet long, 20 feet wide, and 8 feet deep, with a rise of about 14 feet, and an incline in place of the existing locks at the Tardebigge flight.* The cost of this work was estimated at £600,000. Mr. Keeling would prefer adopting the route by Droitwich, joining the Severn above Worcester, which would shorten the canal-route by two miles, concentrate the locks, and avoid the Dunhampstead tunnel; but it would involve raising Worcester Bridge, enlarging a lock above Worcester, and dredging in the Severn, to enable the proposed class of vessels to pass along the Severn above Worcester to the entrance of the Droitwich canal. The great merits of this route are the moderate length of canal that would require improvement before reaching a waterway of adequate size, the undivided ownership of the canal needing enlargement, and the absence of variations in level beyond

* *The Engineer*, 1887 (1), page 499, and 1894 (1), page 471.

the necessary descent from Birmingham to sea-level. It appears expedient to make the enlarged waterway available for the same sized vessels up to Birmingham, as those that can at present ascend the Severn up to Worcester; and it is possible that lifts might advantageously replace locks where grouped together, and be employed at Tardebigge instead of an incline. It seems also advisable to defer the proposed extension of the Gloucester and Berkeley canal to Sheperdine, till the improvement of the Worcester and Birmingham canal has been carried out, unless it is treated as quite a separate undertaking; for the enlargement of the canal is a matter of inland navigation, whereas the extension to Sheperdine is for sea-going vessels, which may become a necessity for Gloucester, in the event of its inland trade with Birmingham becoming largely developed by the enlarged waterway.

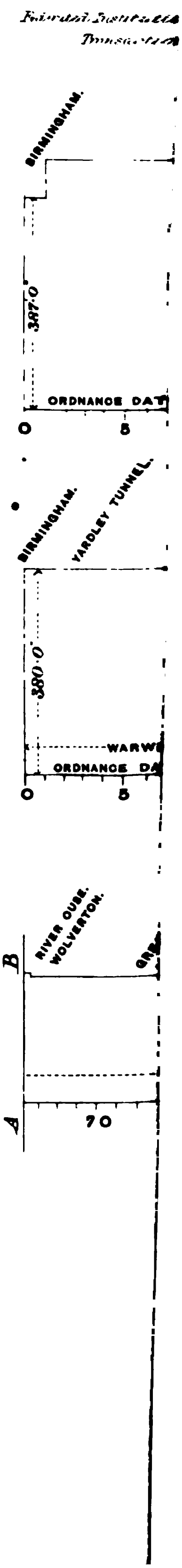
Comparison of Inland Waterways for Birmingham.—A comparison of the three longitudinal sections (Plate XXVI.) illustrates very forcibly the difference in the physical conditions of the three routes. The route to the Thames involves the improvement of 132½ miles of waterway, with successive dips and rises, and consequently numerous locks. The route to the Weaver is 63¾ miles long, only about half the distance to the Thames, but involving an entirely new canal with rises and falls. The route to the Severn is only 28 to 30 miles in length, less than half the distance to the Weaver, and less than one-fourth the distance to the Thames; it merely involves the improvement of a single canal, with no greater variation in level than that imposed by the elevation of Birmingham. From an engineering point of view, accordingly, the Severn route is much the best, simply on account of the shorter distance, and more favourable physical conditions of the intervening country.

The development of a waterway to the Thames would necessitate arrangements with four independent companies; the proposed route to the Weaver would be sure to arouse vehement opposition, and competition with three railway companies; whilst the route to the Severn would be concerned with only one company. Accordingly, in this respect the improvement of the waterway to the Severn would be much easier to arrange; though probably none of the four canal companies on the Thames route would be in the least averse to the enlargement of their waterways.

The proposed new canal to the Weaver would have the advantage of accommodating other districts on its route, to the north of Birmingham; whereas the routes to the Thames and Severn would only give direct accommodation to Birmingham. It has also been stated in favour of this

new canal, that 43 per cent. of the sea-borne traffic of Birmingham is shipped at Liverpool; whilst judging from the traffic on the Warwick and Birmingham, and Worcester and Birmingham canals, amounting to 353,100 and 392,600 tons respectively in 1888, the traffic which goes southwards from Birmingham by inland waterways is fairly evenly divided between the existing Thames and Severn routes, though slightly in favour of the latter. Whatever advantages, however, may be possessed by the route to the Weaver in these respects, appears to be outweighed by its great cost and prospects of opposition.

Gloucester, indeed, is by no means on an equality with London or Liverpool, either as a commodious seaport for the foreign trade of Birmingham, or as a market for its goods; and other conditions apart, London or Liverpool would naturally be preferred, though it must not be overlooked that the route by Gloucester gives easy access to Bristol, Newport, Cardiff, and Swansea. The waterway to the Severn, however, even now appears to attract a little more traffic than the waterway to the Thames; and unless some serious commercial impediment should exist to the development of the waterway to the Severn, and the adoption of Gloucester, Sharpness, or Sheperdine as the seaport of Birmingham, the paramount conditions of cost and shortness of route plainly indicate the route to the Severn as the proper outlet for the water-borne trade of Birmingham. In the face of the financial condition of the Manchester ship-canal, it would be useless to propose the execution of the proposed new canal from Birmingham to the Weaver, with an estimated expenditure of £5,000,000, which would doubtless be exceeded. The route to the Thames appears to have been favourably regarded by the Birmingham corporation, and the scheme of improvement is desirable enough in itself; but the enlargement proposed is scarcely adequate to the present requirements of inland navigation. Moreover, to provide a waterway from Birmingham to the Thames, suitable for vessels of 300 to 400 tons, along a distance of 132 miles, would cost considerably more than double the formation of a similar waterway to the Severn along a length of only 30 miles. Owing, indeed, to considerations of expense, the choice probably lies between the adoption of the Severn route and the abandonment of a much-needed enlarged waterway between Birmingham and a seaport. The writer is, therefore, of opinion that it is very expedient for the Birmingham corporation and all others who are interested in improving the access of Birmingham by water to the sea, to investigate fully the best means, and the cost, of connecting Birmingham with the Severn by a waterway capable of accommodating vessels of 300 to 400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tons, along the route at present traversed by the Worcester and Birmingham canal, as affording a prospect of obtaining the cheapest, shortest, and most feasible outlet for the water-borne trade of Birmingham, in a direction well suited for transit to foreign ports.

The following paper by Mr. W. Salt, on "Canals and their Improvements," etc., was taken as read :—

CANALS AND THEIR IMPROVEMENTS, MORE PARTICULARLY APPLYING TO THE LONDON AND BIRMINGHAM TRADE.

By W. SALT.

Canals in the latter part of the last and in the earlier part of this century were without doubt of the greatest importance to the welfare of this country. As a means of transport they came largely into use in this country at the end of the last century, and although they were then very efficient methods of conveyance, they have, with one or two solitary exceptions, failed to keep pace with the necessities of the age. This fact is made very obvious by some of the antiquated pumping-engines to be seen at some of the old canal works. There is one in Birmingham in the original state in which it was left by Messrs. Boulton & Watt in the year 1796. Canals are practically in the same condition, and they are even as the machines of a hundred years ago, with absolutely no improvement.

A farther defect of the canal-systems in this country is the utter disregard of uniformity displayed in their construction. There appears to have been practically no idea of transferring traffic from one canal to another. Each company made its canal with regard only to local interests, and in several instances the sizes of locks have varied two or three times upon the same line of navigation, efforts being made to cultivate a local trade only.

During the railway mania there was hardly a canal in the kingdom which did not seek either to ally itself with some railway enterprize or sell itself outright for conversion. The railways have obtained the control of many of the chief links in the canal-system, and they now hamper and obstruct any attempt at making either working rates or tolls. Even where they do not use their utmost endeavour to cripple the trade upon the canal, and drive it on to their railways, they make canals almost a dead letter for any through trade from want of repair. A further result of the alliance with railways is that no improvement of any kind has been undertaken by any independent canal company.

Canals have now, the writer believes, reached a very critical period in their history, and unless some large and comprehensive scheme be devised for the consolidation of the main navigation-routes, with a view to their immediate improvement, the time is not very far distant when they will be unable to resist the encroachments of their more powerful competitors, and they, like a number of their less fortunate neighbours, must become derelict. That this was felt to be the case the investigation of a Joint Committee of the Houses of Lords and Commons, which sat in 1872, fully evidences, for in their report they recommend:—

(1) That no inland navigation now in the hands of a public trust shall be transferred to or placed under the control of a railway company, and that if the trustees of an inland navigation or a canal company apply to Parliament for power to purchase compulsorily a canal from a railway company, such purchase shall be favourably considered by Parliament.

(2) That the utmost facilities shall be given for the amalgamation of the adjoining canals with one another, or with an adjoining navigation.

The first step appears to be clearly the amalgamation of so many of the existing companies as are owners of links of a through route, or of any collateral canals between a large producing and consuming district, and the nearest importing and exporting port; and, in the writer's opinion, the larger and more comprehensive the area included in such a scheme the better is the prospect of efficiently competing with the railways. In fact were the whole of the canals south of Liverpool, inclusive of the Trent and Mersey canals, grouped in one scheme, and those of the remaining northern canals in another, there would be far better chances of success, and of making their influence felt in rivalry with the railway companies.

Much has been said of the manner in which such an amalgamation should take effect, whether the whole of the canals should be taken over by the State, or whether it should assume the form of one of the statutory companies as at present constituted, or whether, again, the amalgamation should be in the nature of a public trust administered for the benefit of the various counties or districts through which the canal passes. The former scheme has much to recommend it, but it is very questionable whether a State department can be worked as efficiently as a private enterprize. As to the suggestion of a public trust, the writer thinks that no satisfactory method has yet been suggested, either of raising the necessary capital, or of dividing the proceeds.

The most satisfactory section for an inland canal has yet to be settled, as the requirements of different districts vary so considerably. Unquestion-

ably a large sectional area is desirable for economical traction, but it is questionable whether the desire for large sections is not carried too far. If canals are to compete successfully with railways and become a public benefit, they must not be hampered with too much capital. The expenditure upon improvements should be gradual, and continued from time to time as the requirements of the traffic demand. Mr. Saner gives the sectional area of canals as varying from 130 square feet for the narrow canal to 780 square feet for the Weaver navigation. The narrow canal is, however, what we are most concerned about, for while several have locks capable of passing boats of a width of 14 feet, the cross-section of the waterway would not admit of the passing of two boats on the main lines of the canal, and consequently they must be considered as narrow.

The writer conceives that improvement should proceed somewhat on these lines, viz. :—

(1) Improvement of the sectional area of the waterway.

(2) Improvement of the capacity of the locks.

(3) Traction.

(1) There are few canals that would not admit of dredging to a depth of 5½ to 6 feet, and where the width is small, they might be walled on either side to the full depth of the canal, thus increasing their sectional area and providing the best safeguard against damage from the wash of the water. With such a depth, boats 70 feet long and 7 feet beam could be readily built to carry 40 tons. This size of craft has many unquestionable advantages: It is handy in every sense of the word, there being very few manufacturers who can give more than 40 tons in one consignment, except of low-class articles, such as coals, bricks, roadstones, etc., and even then the 40 tons load has advantages in distribution which the larger boat does not possess. The traction of the small boat is not appreciably greater per ton than that of a barge, and in many instances it is much less. With a canal having an available depth of 5½ feet, a train of eight 40 tons boats could be satisfactorily towed at a cost of 0·10d. per ton per mile. Mr. Wells gives the cost of traction on the Aire and Calder canal for goods at 0·03d. per ton per mile, but this is only attained on a river navigation of such a sectional area as would (in the writer's opinion) enormously increase the capital cost of canals if they were brought up to that standard, and entirely destroy all hope of successful competition for many years. On the Bridgewater navigation, four barges laden with 60 tons each can be hauled at a cost of

0·10d. per ton per mile. Taking these figures, the cost of transport of bricks or coal between South Staffordshire and London, a distance of 150 miles, would be 1s. 3d., to which might be added an improved toll of say 3s. 6d., making a total charge of 4s. 9d., as against the railway rate of 6s. 6d., which at present is charged. As a matter of fact the toll on bricks to London at the present time is less than that stated by Mr. Wells, and the cost of haulage by horse-power is not less than 0·44d. per ton per mile.

(2) Although a very large traffic may be carried upon the narrow canals in small boats, steam traction cannot be applied satisfactorily with the present small locks. To successfully cope with this difficulty, the writer is of opinion that locks of a capacity of not less than nine boats, including the tug, should be contemplated. The dimensions of such a lock would be roughly 220 feet long, 22 feet wide, and have a fall of about 21 feet; and for the economizing of water the locks might be made double. To prevent loss of water when smaller trains of boats than nine were passing, gates might be placed so as to take either three or six boats at once. Of course it will be said that locks are wasteful of water, and that this waste must be made up by pumping; but there is this advantage over a mechanical arrangement, that in times of large rainfall no cost is incurred in supply. Locks are infinitely less likely to be stopped by any defect in the arrangements for their working than are hydraulic lifts or inclined planes. They are less costly to construct and no skilled labour is required to work them. They can be worked as expeditiously (or more so) than any mechanical appliance.

The writer some years ago interested himself largely with what he considered the best form of lift, and for simplicity of working he thought that was the hydro-pneumatic type. But although he gave considerable attention to this and other forms of lifts, he came unhesitatingly to the conclusion that no cheaper form could be adopted than that of a modification of the present double lock, with a suitable pump to raise the lockage water. An efficient pump will raise 1,000,000 gallons of water 100 feet high for 20s. Now, assuming for the traffic from South Staffordshire to London or *vice versa* that water had to be raised by pumps to an aggregate height of 900 feet (and this would, in the writer's opinion, be more than would be required, the water for the supply at the present time not being raised one quarter of that height, the balance being obtained from gravitation-supplies), this would give an expenditure for pumping water for the whole journey to London of about 4d. per ton, and if double locks were used the cost would be 2d. per ton of cargo, or

3d. per ton of cargo, assuming that half of the boats returned empty. Assuming also that 30 hydraulic lifts could be made to take the place of the proposed locks (which is doubtful), and that they could be worked at the cost which Mr. Saner allocates to the Anderton lift if in full work, viz., 0·20d. per ton, this would represent 6d. per ton for lifts to London; the probable figures would be nearer 1s. 3d. per ton, as against 3d. per ton, the cost of pumping.

Such a lock would be capable of working three boats of 21 feet beam and 70 feet long, or three barges of 14 feet beam and three boats of 7 feet beam, or nine boats of 7 feet beam. With moderate dredging, the alteration of ten or twelve bridges and this lock, 14 feet barges could be navigated from Staffordshire to London. For large boats, the reconstruction of the whole of the canals on the route would be involved. The smaller craft and the barge would afford greater facility for larger packages, machinery, boilers, etc., than is offered by any of the railways carrying such goods.

The cost of such an improvement would be moderate as compared with the cost per mile of railways. It would entail no purchase of lands other than that for the new locks. The cost of working such a canal would probably not exceed that of working the present canals except for water, and this would be proportionate to the traffic passed.

(3) Although the method of traction referred to in this paper has been that by means of a steam-tug, it would seem that there is a very large future for the use of motors taking the form of oil or electric engines for propelling the boats, or of oil or electric locomotives for hauling them. That a satisfactory locomotive could be built upon either of these lines which would pass under most of the existing bridges appears to be hardly open to question. As to the latter form of locomotive, canals are particularly adapted for the overhead trolley electrical system.

Mr. Vernon-Harcourt appears to advocate the making of the canal from Birmingham to Worcester of such capacity as would enable boats of some 200 or 300 tons to navigate from the Bristol Channel to Birmingham. Whilst the writer would personally hail with pleasure any improvement of the existing water communication with Birmingham, he cannot lose sight of the fact that London and Liverpool (to which might be added Manchester) are essentially the ports of import and export of the kingdom, and that practically all the merchants are centred at these three places. It would be a hazardous experiment to try and divert the trade from

either. A moderate scheme of improvement would no doubt very largely enhance their trade. There has been for a number of years past, vastly more loading for boats in London for distribution in the provinces than there have been boats to take it away. The great difficulty encountered by the canal carriers is to get paying loads to London, as the large amount of traffic from Birmingham and South Staffordshire is largely absorbed by the railways at very low rates. London and Liverpool therefore appear to be the ports to which any improvements in the canal-routes should be directed. The improvement of the collateral connexions could be effected as the exigencies of the trade required.

The first step, however, is to amalgamate the whole of the existing independent canal companies between certain given points. Then to emancipate those canals which are owned or controlled by the railways, as until this is done, no scheme for any general improvement can be satisfactorily promoted by any party.

Next to this proposal must be placed purchase by the State of the whole of the canals. The question of dealing with the powerful railway monopolies must sooner or later receive attention, and unless the State offers unusual facilities to the independent canal companies or undertakes the task itself, the traders who are removed from the seaboard must either allow their trade to be taken from them by the foreigner, or, if possible, move their works to the coast. The mining industries, however, are so placed that they cannot move their works, their operations must be continued on the site where the mineral is found, and consequently they are in the hands of the carrying power for the time being within the district. Such, unfortunately, is the condition of the mining industry of South Staffordshire and East Worcestershire. The canals in South Staffordshire, which form the natural outlets of their products, have become practically the property of the competing railway, a grave mistake. No improvements have been undertaken since the railway company made itself the monopolist. The mistake, however, is capable of being, to a large extent, repaired, not by making immense waterways or ship-canals, which would never be used by ships, but by emancipation and amalgamation of the existing canals, coupled with a moderate expenditure of capital increased from time to time as the exigencies of the trade requires, and only upon these lines can this be successfully accomplished.

The following paper by Mr. W. H. Wheeler on "Birmingham and its Canal-connexions with the Seaports," was taken as read :—

BIRMINGHAM AND ITS CANAL-CONNEXIONS WITH THE SEAPORTS.

By W. H. WHEELER, M. Inst. C.E.

Birmingham might be regarded as the most central town of England. The trade and industries of the district are of a character specially adapted for carriage by water. In and around the town there exists the largest network of canals of any part of the kingdom, and over these there passed a greater number of tons per mile than on any other system. From Birmingham radiate a series of waterways, which put it in communication with the Thames, the Humber, the Severn, and the Mersey. These canals, however, practically remain in the same condition as when they were originally constructed, and very little has been done to adapt them to the altered conditions of the present day and to enable them to fulfil modern requirements.

Owing to its inland position and distance from the great ports, a system of properly-developed waterways is of the utmost importance to the maintenance and prosperity of the trade and manufactures of the district.

Canals are eminently adapted for the conveyance of the minerals in which The Federated Institution of Mining Engineers is interested, and of those products for the manufacture of which coal forms an essential factor. The Institution is therefore to be congratulated on having afforded an opportunity for eliciting information of a valuable character from the papers which have been contributed, and the writer expresses his thanks for being allowed to add some farther comments.

It was remarked at the meeting by one of the members of the Institution that the most important thing to be done in furthering the prosperity of the mining industry, and generally that of the country, was to cultivate foreign trade, and that the great drawback to this at the present time was the rates which had to be paid for transport compared with other countries.

For economical transport it is essential that any large manufacturing district should be placed in direct communication with one of the great seaports by an efficient system of waterways, both as a means of convey-

ing manufactures and minerals for export and of conveying the food and other materials imported; and also as a means of keeping down railway rates by an independent competitive system. Any district that is not so provided can only carry on its trade at a considerable disadvantage, as compared with those equipped with this advantage. Leeds, Manchester, and Sheffield have all realized this fact; the former by improving existing waterways and assimilating as far as possible the methods of conducting its transport-service to that of the railways; Manchester by making the city itself a seaport; and Sheffield by freeing its waterways from the domination of the railway interest, and by obtaining powers to adapt them to modern requirements, and to allow of the passage of moderate-sized sea-going steamers up to the heart of the town.

Birmingham, to whom, from the nature of its trade, efficient water-communication is even of more importance than to any of these towns, does not yet appear to have realized this fact, and remains, so far as water-transport is concerned, in the same condition as before the advent of railways. Notwithstanding the convincing fact of the value of canals, as evidenced by the large traffic carried on along the waterways in the immediate neighbourhood, practically nothing has been done to bring these up to modern requirements. Small locks, shallow water, and horse-haulage of boats of small tonnage still reign as in former days. The companies which control the several systems round Birmingham have taken no steps to provide steam-haulage, or to act themselves as carriers, or even to adopt the conveniences afforded by railway transport. The whole traffic is left to the slumbering energy of the bye-trader and barge-owner. All attempts to open up an improved waterway to the seaports have hitherto failed, and the advantages to be derived from economical transport by water still lie dormant.

The full value of a waterway cannot be realized so long as old ways and antiquated customs are maintained, nor until the service conforms to modern ideas and requirements. Since the advent of railways, the functions of canals have changed, and all attempts to maintain them with commercial success on the old footing must fail.

During the last few years, considerable attention has been directed to the subject of canals and water-transport, and a very great number of papers and pamphlets have been written on the subject. The essence of these consists in a lament that a portion of the canal-system has fallen into the hands of the railway companies; and in a comparison between our canal-system and that of France and Belgium. As regards the former, where the necessity arises the remedy can be secured, as in the case of the

transfer of the canals belonging to the Manchester, Sheffield, and Lincolnshire Railway Company to an independent management. As regards the second, the analogy does not hold good. The circumstances of this country and those of France and Belgium are entirely different. In the latter the waterways are owned by the State, and the works of improvement are carried out by the Government. In England, every work of the kind is carried out by private enterprize, and must have a reasonable chance of commercial success to be taken up. Again, England is a sea-girt nation, with no less than eight first-class ports in a coast-line of 1,820 miles. Communication between these by coasting steamers is therefore easy, and can be accomplished in much less time and at less cost than by canal. There is no large manufacturing town in England that is more than about 80 miles in a direct line from a first-class seaport; and taking the country south of the Firth of Forth there is only 42½ square miles to each mile of coast. France has only two first-class ports, one in the north and the other in the extreme south, over a coast-line of 1,360 miles. Its capital city is 100 miles from the nearest seaport, and the towns in the centre of the country are from 250 to 300 miles from either Havre or Marseilles. For every mile of coast-line there is 162 square miles of country behind it. Belgium has one large seaport and only 50 miles of coast-line, with 227 square miles of country to every mile. Germany has only two first class sea-ports, both situated on its northern coast; Frankfort and Berlin are distant from these about 250 miles, and for every mile of coast-line there are 231 square miles of country. The necessity of an extended system of inland water-communication for the distribution of produce and materials is therefore of far more importance in these countries than in England.

The numerous opportunities which the writer has had of considering this subject has convinced him that the main service to be rendered by canals in this country is by affording communication, between large inland towns and the seaports, for the conveyance of heavy produce where quick delivery is not essential; and that it is only on such lines that it will pay commercially to expend capital in enlarging and improving the existing canals. For such a service the waterway requires to be sufficiently large to allow of the passage of steamers carrying goods in boats of sufficient size, and moved at a speed adequate for a reduction of the working expenses to a minimum, and of such a character as to be able to navigate along the coast or across the Channel to the Continent. Such a waterway would be provided if the dimensions of the Aire and Calder system were adopted, namely, locks 215 feet long, 22 feet wide, and 9 feet depth of water.

A waterway capable of navigation by coasting-steamers has already been provided from the Severn to Worcester, as described in Mr. Marten's paper, and there now only remains the 30 miles of canal from Worcester to be improved to complete the system to Birmingham.

In the competition which prevails between Great Britain and other countries in the carrying trade of the world, the size of ocean-going vessels is continually being increased, and it is not an unusual occurrence for cargo-steamers trading between this country and the more distant colonies to carry 10,000 tons of cargo in one bottom. The draught required for vessels of this size makes only ports of the first-class available for them. The tendency is therefore for the import and export trade of the country to concentrate at these large seaports, and for cargoes to be distributed to the smaller seaports by coasting-steamers. This practice already prevails to a considerable extent, and an inland town that has a waterway of sufficient capacity to allow of the passage of one of these small coasting-steamers, carrying from 100 to 300 tons, has all that is required.

With the exception of certain localities, where there is a large local trade of a nature suitable for water-transport, it is only the canals connecting large towns and seaports that it would pay to bring up to a first-class standard. The second-class canals may be made to serve an useful purpose and pay a moderate dividend to the owners as feeders and distributors, and by performing those functions in agricultural districts which it is now sought to provide by light railways. For these purposes boats carrying small cargoes at small speeds are sufficient. Without any great structural alterations, such canals if adapted to the modern system of transport and the service more nearly assimilated to that of the railways, might be made to serve a very useful purpose, not only as an economical means of conveyance, but as keeping prices within moderate limits on the railways.

Mr. Wells, in his paper, calls attention to the deplorable condition of the canal-system between the Thames and the Severn, and intimates that this is one of the main systems that should be developed into a first-class canal. From this opinion the writer differs. The necessity for water-communication between the Thames and the Severn is admitted, but this can be accomplished in less time and at half the cost by small coasting-steamers than by the canal system, even if improved. The distance round the coast may be considerably longer, but less power would be expended in driving a boat in open water than in hauling the same load in several small barges through a shallow and narrow waterway, and in raising and lowering it nearly 500 feet above sea-level through 165 locks.

Birmingham is situated about an equal distance from the Thames and Humber seaports on the east side, and about half that distance from the Mersey and the Severn on the west. The main difficulty to be overcome is the ascent and descent of between 400 and 500 feet above sea-level. With modern appliances this forms no serious objection. The question of the most advantageous seaport with which to connect is lucidly set forth in the paper by Mr. Vernon-Harcourt. The writer agrees with Mr. Vernon-Harcourt and Mr. Marten that the plan laid out by Mr. Keeling offers the greatest advantages, and that the Severn is the natural seaport for Birmingham. The length of canal from Birmingham to Worcester that would require improvement is only 30 miles, and the cost by this route is considerably less than that of any other scheme that has been proposed. It is useless to attempt any scheme that will not offer a reasonable prospect of being commercially successful, and the expenditure of £600,000 for this outlet seems much more likely to give a return than the £5,000,000 estimated for the Weaver route.

A canal-system, affording accommodation to steamboats of 300 tons and capable of coast-navigation, would at once give to Birmingham sea-communication with Bristol, Cardiff, Swansea, and the other Severn seaports, and also with Liverpool, the Thames, and with Rouen, Antwerp, Paris, and all the Continental seaports.

Considering the immense advantage which such a scheme is likely to confer on Birmingham by giving it an outlet to the sea, and on Cardiff by affording facilities for the import trade which it so much desires, it is a matter of surprise that communication with the sea by a canal of adequate dimensions has been so long deferred.

Mr. J. A. Saner (Northwich) wrote that he agreed with Mr. Marten's remarks upon the necessity for the removal of overhead bridges of such low headway as that at Westgate near Gloucester, on all navigations which are to be navigated by steamers, even if their masts are made to lower. On the other hand, his (Mr. Saner's) paper would support Mr. Marten in his proposal to build special vessels for navigating the Severn with the bridge as it was. His experience on the Weaver fully corroborates Mr. Vernon-Harcourt's view of the rapidity with which locks can be worked with cylindrical sluices; these have, however, the disadvantage that they do not clear the detritus and mud away from the bottom of the lock, and so it is left to accumulate in the gate-recesses; this obstacle, however, is easily

overcome by providing small sluice-paddles at the side or in the lower portion of the gates. He strongly supported Mr. Vernon-Harcourt's view as to the possibility of using hydraulic canal-lifts on an extensive scale. He had had charge of the Anderton lift for the past eight years, but he had also visited the French lifts, and he might repeat here what he had intimated in his paper, that during the severe frost he had kept the Anderton lift working until the Trent and Mersey canal was absolutely stopped for traffic. With his farther experience of severe weather, he was still assured of the possibility of working such lifts in the English climate, provided due precautions were taken to have the pipes and valves properly protected. Although the engineering difficulties to be overcome in the route from Birmingham to the Mersey *via* the river Weaver are no doubt greater than those which will be met with in connecting the same city *via* Worcester with the river Severn (and he had travelled over both routes), he could not but think that the very much more densely-populated country, including the Potteries of Staffordshire, through which the Mersey canal would pass, would be greatly in favour of that route. Not only because there would be direct connexion by water between the three large centres of industry, but the existing works of the Weaver and the Manchester ship-canal, etc., would amply accommodate the increased traffic for many years. His own view of the case was, that from the Midland counties there was not only room for the Birmingham to Liverpool canal *via* the Weaver, but also for the Birmingham to Bristol canal *via* the river Severn.

Mr. GEO. W. KEELING (Cheltenham) wrote that Mr. Vernon-Harcourt in his interesting paper had so very clearly stated the facts, and he was generally so much in accord with the views which that gentleman had expressed that he had but few remarks to offer. The result of some years' experience of the available water-supply to the Worcester and Birmingham canal had led him to the conclusion that it would not be more than sufficient to be relied upon in all seasons to supply and work the traffic on a canal of the proposed dimensions—of 66 feet in width and 9 feet in depth—large enough to navigate vessels carrying 200 tons (or lighters carrying 250 tons). This size would be convenient for the use of coasting-steamers carrying Birmingham goods to the Bristol Channel and other ports. No doubt a 400 tons vessel would be better for imported grain and timber, but the supply of water would be a serious difficulty for a canal large enough to accommodate such vessels, and the cost of the works would be largely increased. The configuration of the ground between Tardebigge and Stoke Prior was more

favourable for an inclined lift than for a series of vertical lifts, and for this and other reasons he thought that an inclined lift on this rise of 250 feet would be the most economical in cost of construction and in working; but it was not unlikely that the chain of six locks at Dodderhill, and other sets of six locks might be advantageously replaced by a hydraulic lift. An advantage of the Droitwich route, compared with Worcester, was that it would avoid costly works on the portion of the canal passing through the city of Worcester, and, moreover, would make use of the water-supply from the river Salwarpe. The canal between Sharpness and Gloucester was a ship-canal, and Gloucester, by water, was within 60 miles of Birmingham. The river Severn (Gloucester to Worcester, 30 miles) was navigable for vessels carrying at least 200 tons, and it was anticipated would be available for vessels of nearly 350 tons. The Worcester and Birmingham canal (29 miles in length) is an independent waterway. The estimated cost of the improvements was as stated about £600,000, or, together with the acquisition of the canal, say £800,000. The estimated increase of traffic, in order to pay 5 per cent., was 800,000 tons only, and the cost of transit between Sharpness docks and Birmingham was 3s. 6d. per ton on heavy goods. The acquisition of any property other than the Worcester and Birmingham canal was not necessary, for 200 tons vessels could, as already mentioned, reach Worcester, and by means of the improved canal, would furnish access between Birmingham and the seaports in the Bristol Channel or on the coast, Liverpool, Ireland, etc. It cannot therefore be described as a costly scheme, but by its means the desired relief in cheaper transit could be obtained at the least possible expenditure. The Bristol Channel imports to the Midlands exceed those of either London or Liverpool. They consist chiefly of grain and timber, for which it is more important to secure cheap transit than for miscellaneous manufactured goods of light weight for export.

Mr. Lyonel Clark (London) wrote that he had been engaged as assistant to his uncle, the late Mr. Edwin Clark, in the survey of the route for the proposed canal of large section from Birmingham to Liverpool, referred to in Mr. Vernon-Harcourt's paper. This canal was surveyed by Sir James Brunlees, who acted as the engineer, Mr. Clark's share in the undertaking being the designing of the hydraulic lifts similar to those which he had designed for the French and Belgian governments. As he (Mr. L. Clark) had been the resident engineer in charge of these lifts he was naturally asked to look over the route of the Birmingham and Liverpool canal with a view to the best placement of the necessary lifts. He might say that no difficulties were met with, but of course care had to

be taken (similar to that necessary in the case of the Belgian lifts, situated in the Centre coal-field), that sites were not selected in the vicinity of mines which might endanger the stability of the lifts. This danger, however, only existed in the section between Birmingham and Wolverhampton, it was not a serious difficulty, and generally speaking the route adopted was perfectly feasible. The lifts on the proposed canal were designed to take vessels 100 feet long by 22 feet beam and drawing 9½ to 10 feet of water, with a carrying capacity of 380 to 400 tons. The lifts were double, that is, one trough served the up and the other the down traffic. With the past experience of the Belgian and French lifts to guide them, these machines were naturally considerably simplified, and consequently the cost reduced so much that the estimate for an average 50 feet double lift for boats of the type above-mentioned did not exceed £30,000. This figure shows a considerable reduction on the cost of the Belgian lifts, but then it must be remembered that the latter were the first of the kind constructed, and were built for the Government without regard to economy. This economy, however, was not gained at the cost of efficiency, and, indeed, in one or two points they would be an improvement on the Belgian lifts. The most important question, however, in the design of these lifts was that of the size of the boat. This point was a very important one, and required considerable thought. It was evident that so important a canal, with its numerous branch waterways, would require a class of vessel to be built specially for use thereon, and on all the new canals which would be sure to adopt the same type. In other words, these boats would form a type for a large portion of the canals of England. The boats navigating the French and Belgian canals and the larger type that are to be found on the Meuse and the Rhine and other great Continental rivers are well known. On English canals, however, with the exception of the Weaver navigation, it may be said that there are no boats of any large size, for "monkey barges" and even "dukers" can never carry enough cargo to make a canal a paying investment. The French and Belgian boats, whilst of the right capacity, were considered to be rather too long for handy navigation, and as they would have to cross the estuary of the Mersey they would undoubtedly be too weak. It was decided, therefore, in consultation with Sir J. Brunlees, to take a shorter and stouter vessel as a type. Eventually the length was settled at 100 feet, and in order to get the necessary carrying capacity the draught was increased to 10 feet, as it appeared better in every way to expand in the direction of draught rather than beam. Passing through valuable land, and indeed

over a portion of the route, following and widening existing canals, it was evidently an advantage to take as little surface as possible whilst the water-supply, a serious difficulty over a portion of the route, would be improved by the lesser area exposed to evaporation. The advantage of extra depth also affected the boats themselves as it would certainly enable them, for short voyages at least, to take the sea, and so place Birmingham in direct communication with many of the smaller ports. Lastly, lifts of these dimensions would accommodate the existing boats employed on the Weaver navigation. He would not like to say that such a type of boat would be the best in all cases; indeed in some countries it would not be. For instance, the writer's firm had lately been in correspondence with the Government engineer with regard to lifts on the Trent Valley canal in Canada, to accommodate vessels of a length of 134 feet, a beam of 33 feet, and a draught of 6 feet. In a country like Canada, where land is not yet high-priced, such a section may be the best, but he did not think that this would be the case with the Birmingham canal. At any rate the question was an extremely interesting one, and if canals were to come into favour again in England, as he firmly believed they would, it was one that would have to be settled. He would like to see The Federated Institution of Mining Engineers leading the way in this direction and settling on a type of boat, keeping in view the adoption of lifts, which from their cheapness, rapidity of working, and great saving of water, must in some cases at least be reckoned on, so that a future canal-expansion may not be hindered hereafter by a fresh "battle of the gauges." Mr. Vernon-Harcourt in his present paper favoured the Gloucester route on the score of smaller expense and greater facility. On these grounds there could be no doubt that it was the best, but one could hardly imagine that a city of the importance of Birmingham would seek only the cheapest method. What it would probably ask was, which was the best? The answer to that question could only be—the Liverpool route. There were no industrial districts lying south of Birmingham, and even when the river Severn was reached there was no shipping port of great importance until Cardiff, Swansea, or Bristol were met with in the Bristol Channel. These ports, it must also be remembered, are not what one would call general ports, but rather special in their shipments, dealing indeed very much in the same class of exports as Birmingham, and being moreover manufacturing centres for a similar type of work. The river Severn is therefore merely a port for Birmingham exports, with no return freights, and besides offers no great development of traffic along the route. By

the Liverpool route, on the contrary, the canal would pass through the most productive portions of England. Beginning with Wolverhampton, it would pass through Stafford and the Black Country with its exports of heavy goods; it would pass through the salt districts; it would join the Weaver, the most successful navigation in England, and by this river it would connect both to Manchester and Liverpool. All these districts produce heavy imperishable goods of precisely the class which seeks canal transit. At the end of the canal, there would be the port of Liverpool, a general place of consignment and not a competing manufacturing centre, whilst Manchester could exchange her heavy stuffs for Birmingham's machinery. With these facts before the members, it could not be doubted that, although the capital required might be larger, this route would give a better paying return than the shorter and less expensive one to Gloucester. It had been advanced against the Liverpool route that it would have to contend with the opposition of the railway companies, and also that existing canals would have to be purchased. The latter condition, he ventured to think, would not be a disadvantage. In the inspection of the route, Sir J. Brunlees and Mr. E. Clark went carefully into this matter, and came to the conclusion that there would be no practical difficulty in enlarging the existing canals without interrupting the traffic beyond a day or two at a time. If this plan were adopted, the effect would be that the new company would, from the very first, be earning money, and be in a position to pay a small dividend to its shareholders. It was difficult to say what the opposition of the railways would be, but railway directors were, as a rule, men of sense and knowledge; and with the fact, which must now begin to stare them in the face, that the existing lines were hardly sufficient to cope with the ever-increasing passenger and goods traffic, it was quite possible that they might ask themselves whether, instead of doubling or trebling the railways at an enormous expense, it would not be wiser, certainly not to oppose, and possibly to assist, a means of transport that would relieve them of the class of goods that are most suitably conveyed by water-carriage, and confine their energies to coping with the passenger traffic which will certainly spring up along the route of a canal as fast as the canal itself carries goods. In France and Belgium, the State, the owner of every means of intercommunication, was constructing canals and railways side by side, and allowing each to take the traffic that suited it best. It would be optimistic to hope that we should ever arrive at that consummation, but he (Mr. L. Clarke) believed that if one successful canal were started, there would be a great future development in this direction. It

appeared to him that a communication between Liverpool, the largest seaport, and Manchester and Birmingham, the two largest manufacturing centres in England, was a scheme that promised the greatest measure of success. In conclusion, he might say that although he considered the Liverpool route the best, he would not say a word against the Gloucester scheme, which was one that he thought would certainly soon follow the formation of the Liverpool route, as it was a simple, short, and convenient route, and by replacing the locks where practicable with lifts so as to save time and water (a consideration at the Birmingham end), it could undoubtedly be very cheaply constructed. Nevertheless, in his mind it could not compare with the Liverpool route, which was the only practical solution of the problem of connecting Birmingham with the sea.

Mr. Samuel Lloyd (Birmingham) said that in 1882 a motion was made in the House of Commons for the appointment of a committee, which awakened in Birmingham and indeed all through the country a very considerable interest in canals. The commission issued a lengthy report full of useful matter. The Council of Birmingham appointed a committee to examine into the different canal-routes between Birmingham and the sea. The committee had to report in which direction the greatest quantity of goods were sent from the centre of England to the coast. They found that of the goods Birmingham and neighbourhood exported 40 per cent., and 19 per cent. of the imports were received *via* London; and *via* Liverpool, 43 per cent. of the exports and 24 of the imports. The Severn ports were most admirable, but the traffic would not go in that direction. They only exported through the Severn ports 3 per cent. and received 25 per cent. In South Wales, exports 3, imports 8; other ports, exports 1, imports 7. If they only had a Liverpool with its miles of docks at Sharpness the whole question would be solved, as the money would be subscribed in a month to improve the canal, but the difficulty was that Sharpness was not a port. If they could only get the goods to Liverpool or London, the ships would there take them to every part of the world.

Mr. Beriah Shepherd (Edgbaston) said that the line for a canal from Birmingham to the Mersey was proposed by himself previous to 1890, and at his suggestion Sir James Brunlees and Mr. McKerrow were instructed to make the survey. Mr. Harcourt said that "the scheme would undoubtedly provide a waterway for Birmingham to the sea, quite on a level with the largest inland canals on the Continent; and the proposed system of lifts would enable the great changes of level to be rapidly

accomplished with a small expenditure of water. This canal, however, would be a very costly work, being estimated by its promoters at £5,000,000." Whatever may be the advantage of the proposed route for a canal to the Severn, by reason of its shorter distance and consequent smaller cost, he believed that he would have little difficulty in showing that the importance of the districts to be served by the canal to the Weaver far outweigh any considerations of the cost of construction, which by no means assumed the large proportions indicated by Mr. Harcourt. It is proposed to construct the Birmingham and Liverpool ship-canal (which, as will be seen, is not intended for vessels of more than 400 tons) in three sections: (1) From the Weaver to Stoke-upon-Trent; (2) from Stoke-upon-Trent to Wolverhampton; and (3) from Wolverhampton to Birmingham (if required). The cost of No. 1 and 2 sections, viz., from the Weaver to Wolverhampton, as estimated by Sir J. Brunlees and Messrs. McKerrow and Clark, was £2,167,450, exclusive of land, of which about 800 acres would be required: some 7 miles would pass through the Duke of Sutherland's estate. The late Duke of Sutherland expressed himself most favourably as to the importance of water-communication to the industries of the Potteries districts, and said that he would render every assistance, and accept paid-up shares for the value of the land required for the undertaking. He (Mr. Shepherd) estimated that 800 acres of land, and compensation for disturbance, etc., would cost £150,000, and adding the estimated cost of the canal to Wolverhampton, £2,167,450, the total cost would be £2,317,450, or about half the amount mentioned by Mr. Harcourt. The sides of the proposed canal are to be concreted to a depth of 6 feet below water-line. This lining would allow boats to run at almost any speed, as the displacement of water would not affect the embankments, and further, it would provide wharfage along the whole length of the canal. The hydraulic lifts would change the levels at the rate of 20 feet per minute: the variation in level between the Weaver and Wolverhampton was 746 feet, and in his opinion the journey from Wolverhampton to Liverpool would easily be accomplished within fourteen hours. He might also mention another section which was under contemplation, viz., the improvement of the Trent and Mersey canal from Stone to Burton-upon-Trent. He might also direct attention to the great importance for traffic of the districts through which this canal would pass; probably there was not another canal-route that would give anything approaching the amount of traffic that could be sent by this canal to the Weaver. Wolverhampton, South and North Stafford-

shire, with its coal, iron, and pottery industries, would contribute a constant and a largely increasing traffic, ensuring a large and permanent source of revenue. Shut out of sea-communication at a cheap rate as those districts now are, he considered that unless some such facilities were afforded, such as a really efficient waterway to the sea, the heavy-iron trade of those districts was doomed to extinction at no distant date. The cost of conveyance from Wolverhampton to Liverpool would not exceed 6d. per ton, and this sum would pay interest at the rate of 10 per cent. on barge and steamer, and also cover the working-charges.

A MEMBER suggested that the Worcester canal, and a mile or two of docks at Sharpness, specially to accommodate Birmingham traffic, could be together made at less cost and trouble than the proposed canal to the Weaver. It was a mistake to put all one's eggs in one basket, and for many reasons it was a mistake to throw so much traffic into the single estuary of the Mersey. Moreover, the future tendency of American trade was to move from the Mersey towards Southampton and the Bristol Channel ports.

Mr. E. D. MARTEN wrote, with respect to the various schemes of improved canal communication between Birmingham and the sea-board, that, in his opinion, Mr. W. H. Wheeler had put the case in a nutshell when he said that "It is useless to attempt any scheme that will not offer a reasonable prospect of being commercially successful," and he suggested to the promoters of the Liverpool scheme whether a canal of much smaller dimensions than what was proposed, but yet of sufficient size for the economical use of steam-haulage, would not be more likely to command the confidence of the investing public than the larger canal they favoured, whilst offering practically the same advantages with regard to cheap transport of goods. In the year 1886, the writer's late father reported to a body of Midland traders as to the improvement of the canal-system between London and Birmingham, and he then arrived at the conclusion that the best form of improved canal was one having a top-width of 45 feet, a bottom-width of 21 feet, a navigable depth of 8 feet, and with locks 160 feet long by 14½ feet wide, with 7 feet of water on the sills. Such a canal was well adapted to the use of steam-haulage, and the size of the locks was such as would admit of the passage through them of trains of steam-tugged canal boats, or of single steam vessels carrying 140 tons of cargo. The canals thus reported upon were all free from railway control. A detailed survey, lasting many weeks, and costing a large sum of money, was made by the writer and Mr. Gordon Thomas of the Grand Junction canal. It was found, as the result of this survey, that the very moderate improve-

ments contemplated would cost (exclusive of the purchase of the canals themselves) about £1,250,000, the distance being 132 miles. The *pro rata* cost of similarly improving the existing 65 miles of canal between Birmingham and Liverpool, *via* the Weaver navigation, would probably be somewhat heavier, owing to the great difficulties which would be met with through the mining district between Birmingham and Wolverhampton, and the cost of a new connecting canal at the Weaver end; but it would not be likely to exceed £850,000. The promoters' estimate for a new Liverpool ship-canal, stopping short at Wolverhampton, was £2,317,450, whilst the estimated cost of carrying it on to Birmingham (the only means by which it could have the smallest prospect of success) appeared to be too large for publication. The existing 65 miles of canals, for the most part, were undoubtedly railway-owned, but in view of the Sheffield and South Yorkshire precedent, this should present no great difficulty. The advantage of the proposed new ship-canal, as compared with the suggested improvement of the existing canals, would be (if carried into Birmingham) that goods would of course be conveyed more cheaply to the ocean liners at Liverpool in one bottom of 400 tons rather than in bottoms of 140 tons only, and farther, that goods intended for coastwise destinations, or for the Continent, would be put on board at Birmingham and carried without transhipment to the port for which they were intended. These advantages, however, would probably be outweighed by the enormous burden of capital which the new ship-canal would have to sustain, as compared with the moderate outlay required for the suggested improvement of the existing canals. It must also be borne in mind that the purchase money to be paid for the existing canals in their present state would be determined almost entirely by their net revenue, which would become a valuable asset in the hands of the purchasing company, and that a company constructing a new canal would start without any such advantage. With the Severn route the case for a small ship-canal was entirely different. There already existed a waterway for sea-going steamers of 300 tons burthen up to Worcester, within 30 miles of Birmingham, and thence to the latter city there was a canal entirely free from railway control. This canal, Mr. G. W. Keeling, the chief engineer to the navigation of which it formed a section, estimated could be made navigable for barges of 200 to 250 tons burthen for £600,000, and on the dimensions which form the basis of his estimate, it was clear that for a comparatively small farther outlay the sea-going steamers of 300 tons burden which already could come to Worcester might be accommodated on the canal, up to Birmingham. The extra expense of so doing would be well repaid by the great gain resulting from the expenditure, whereby sea-going

steamers of 300 tons burthen might be loaded in Birmingham and deliver their cargoes coastwise or at Continental seaports. The writer was aware that many traders preferred London or Liverpool as ports of export, instead of the Severn ports. He considered, however, that there was sufficient traffic to support improvement in all these directions. Those traders who would gain by the establishment of a line of sea-going steamers between Birmingham and Continental or other over-sea ports should support the Severn scheme, which was by far the cheapest for such an object, and which would also place them in direct water-communication by steam-vessel with such considerable ports as Cardiff, Bristol, Newport, Swansea, Milford, etc. Those traders, on the contrary, who favoured the ports of London or Liverpool, would find the capital for the improvement, on the lines above indicated, of the canals between Birmingham and either or both of those places, bearing in mind, however, that the canals on the London route were free from railway control, whilst to get to Liverpool it would be necessary either to wrest the existing canals from the hands of the London and North Western Railway Company, or else to make an entirely new competing canal, a scheme for which Parliament would require to hear very strong reasons indeed before sanctioning it. Throughout his (Mr. Marten's) remarks the writer had, for convenience, used the expression "steam-haulage." He was of opinion, however, that the best form of motor will eventually be found to be either oil or compressed gas, as an oil or gas engine and its fuel takes up much less space than a steam engine and fuel, and consequently more cargo could be conveyed for the same money.

Mr. L. F. Vernon-Harcourt, in reply, observed that he agreed with Mr. Wheeler in the view that the conditions of inland navigation were different in Great Britain to those on the Continent, owing to the great length of coast-line and the number of seaports of Great Britain in proportion to its area, as compared with most of the countries of continental Europe. Birmingham, however, was a large, flourishing inland town at a distance from the sea-coast, and possessing, with the surrounding districts, a trade in bulky goods specially suitable for conveyance by water; and therefore it appeared that Birmingham ought to be provided with an adequate waterway to a seaport, for the reduction of the rates of transport, the expansion of its trade, and to enable it to maintain its position against foreign competition. He did not think that it would be possible to obtain Government aid for the improvement of the waterways of Great Britain, as suggested by Sir E. Leader Williams, and he much doubted the expediency of attempting the improvement of the whole network of waterways; but the Government might advantageously facilitate,

as far as possible, the amalgamation of the separate links of important through routes under a single trust, so that these waterways might be made uniform in dimensions, and each route placed under one management. The only route from Birmingham to the sea which had been advocated in the discussion as preferable to the Gloucester route was the route to the Weaver. This route was very naturally preferred by Mr. Saner, the engineer to the Weaver navigation, for its adoption would greatly augment the traffic on the Weaver, and also by Mr. Lyonel Clark, who had been concerned in the preparation of the scheme, the main feature of which was the employment of hydraulic canal-lifts on a large scale, with the construction of which he was so intimately associated. He had entered upon the consideration of the subject for the paper which he had been asked to present to the meeting without any preconceived notions, and had arrived at the conclusion that the Gloucester route was the most practicable, as, owing to the physical conditions, it was much less costly than any other; and as its formation involved negotiations with only a single canal company, its accomplishment appeared far more feasible. Irrespectively of the great obstacles in the way of arrangements with other companies along the route to the Mersey and the large capital cost of the undertaking, he should have preferred the route to Liverpool by the Weaver, both on account of the connexion thereby afforded with Manchester and Liverpool, and also owing to the districts of the Potteries being served by this route. He had not the slightest engineering objection to urge against the Weaver route, if the capital could be raised and the other obstacles overcome; but he seriously doubted the possibility, under present circumstances, of obtaining the large capital required; and he was also uncertain whether the traffie could be thoroughly relied upon to secure an adequate return, even assuming that in such a large sum the estimated cost was not exceeded. Mr. Shepherd, indeed, who had stated that he was the originator of the scheme, had given a considerably lower estimate, but only for a canal between Wolverhampton and the Weaver, which was only a portion of the scheme, and would not satisfy Birmingham; whilst he had not brought forward any reasons for modifying the estimate prepared by Sir James Brunless and Mr. McKerrow, which was published with the details of their scheme. As an engineer and a man of business, in spite of the engineering attractions of the Weaver route, he had felt bound to give the preference to a waterway which could secure Birmingham access to the sea at a moderate cost, fully within the amount which Birmingham might raise without the aid of financiers, and which afforded a good prospect of an adequate return on the capital expended. Mr. Lloyd

had stated that the traffic with Birmingham passed mainly through Liverpool and London, and it was quite possible that the energy of the London aud North Western Railway Company, who controlled the Birmingham canals, had directed the bulk of the traffic of the district on to their lines. The Worcester and Birmingham canal, however, even in its present condition, had a larger traffic than the waterway between Birmingham and London; and the route by Gloucester was the shortest and easiest outlet by water for the export and import trade of the Birmingham district with foreign seaports. The vessels navigating the inland waterway could tranship their cargoes at any of the Bristol Channel seaports; and communication with every part of the world was quite as easy from Bristol, Newport, Cardiff, Barry, and Swansea, as from Liverpool or London. The great object was to obtain for Birmingham an adequate waterway to the sea at a reasonable cost, and thus, besides improving its facilities for commerce, relieve it from its dependence on railways, and place it in a more favourable position for competing successfully with foreign manufacturers. It was a somewhat utopian vision to imagine Birmingham connected by ample inland waterways with London, Liverpool, and the Bristol Channel ports, when Birmingham had hitherto failed to obtain any improvement in its antiquated waterways, and when none of the various proposals for a first-class waterway to the sea had ever passed beyond the region of speculation. Under these circumstances, it was evident that the best prospect of a solution of the difficulty lay in the selection of the least costly and most feasible of the schemes. The enlargement of the Worcester and Birming-canal unquestionably complied with these requirements, and would place Birmingham in direct communication by water with the Bristol Channel ports; and these flourishing ports, with deep entrance channels and unimpeded access to the sea, would place Birmingham in easy connexion with every port of the world.

Mr. J. Head (London) said that he had great pleasure in proposing that the best thanks of the Institution be given to Messrs. Marten, Vernon-Harcourt, and other gentlemen for the able and instructive papers which they had communicated to the members.

Mr. Emerson Bainbridge (Sheffield) seconded the motion.

The resolution was carried.

Dr. Haldane read the following paper by Mr. W. N. Atkinson and himself on "Investigations on the Composition, Occurrence, and Properties of Black-damp":—

INVESTIGATIONS ON THE COMPOSITION, OCCURRENCE, AND PROPERTIES OF BLACK-DAMP.

BY JOHN HALDANE, M.A., M.D., LECTURER ON PHYSIOLOGY, UNIVERSITY OF OXFORD, AND W. N. ATKINSON, H.M. INSPECTOR OF MINES.

Black-damp is a gas or mixture of gases known to be frequently met with in old workings or other ill-ventilated parts of coal-mines. It is not, however, generally recognized that probably no other impurity is so abundant in the return air of mines.

The most important characteristic of black-damp is the fact that when mixed in sufficient proportion with air it extinguishes a lamp. It is, moreover, pretty well known that a proportion of black-damp just sufficient to extinguish light, does not cause any marked respiratory distress. In this latter respect, as well as in respect of its origin, black-damp contrasts with the more poisonous mixtures of gases known as "after-damp," "white-damp," "gob-stink," or coal-smoke.

As regards the composition of black-damp little seems hitherto to have been ascertained. It is generally assumed, however, to be carbonic acid. This assumption seems to be chiefly based on the fact that it frequently lies along the floor of workings with air above it, and is thus like carbonic acid, heavier than air. In a paper read by one of us before the British Association in August, 1894, it is argued that black-damp is probably nothing but the residual gas left on slow oxidation of the carbon and hydrogen of coal by the air, and that, at any rate, it is neither wholly nor chiefly carbonic acid.

When carbonic acid is mixed in increasing proportions with air, a man breathing the mixture begins to pant long before the point at which a light burning in the same mixture is extinguished.* To produce a mixture which will extinguish a light before it affects the respiration of a man, it is necessary to add to the air, along with each volume of carbonic acid, more than three times as much nitrogen.†

* An experiment demonstrating this point is described by Messrs. Haldane and Lorrain Smith, *Journal of Pathology and Bacteriology*, 1892, vol. i., page 175.

† This follows from the fact that air requires an admixture of about 15 per cent. of carbonic acid (according to Dr. Clowes) to become extinctive, whereas about 3·5 per cent. of carbonic acid is sufficient to affect respiration.

Through the courtesy of the managers of the Midland Coal, Coke, and Iron Company, North Staffordshire, and the Lilleshall Company, Shropshire, we have recently had exceptional opportunities of making observations on black-damp as found in various pits, and the results obtained appear to us to throw a considerable amount of new light on the subject.*

1.—Composition of Black-Damp.

To ascertain the composition of black-damp, we analysed samples obtained from various pits and seams. The results are given in Table I. In some cases the gas was obtained as it issued from an iron pipe inserted through a stopping. In other cases we obtained the samples by simply advancing with an electric lamp as far as was possible, along levels or down dips where black-damp was present. With the help of a small aspirating hand-pump, a clean and dry bottle of about four ounces capacity, provided with a tightly-fitting cork previously boiled in paraffin wax, was filled with the gas. For the analyses these bottles were opened under mercury, and the carbonic acid, oxygen, marsh-gas, and nitrogen accurately determined. In many cases, as will be seen below, the analyses were in duplicate; and the individual results never differed by more than 0·02 per cent. from the mean of the two results.

The results are given in Table I. It will be seen that the black-damp was always mixed with air, and frequently with fire-damp. The proportion of air is calculated from the oxygen percentage, and the proportion of marsh-gas being also known, the composition of the residue is that of the black-damp.

Table I. shows that the undiluted black-damp was very constant in its composition, and consisted of from 85 to 88 per cent. of nitrogen, and from 15 to 12 per cent. of carbonic acid. The only exception was in the case of the third sample, in which the black-damp consisted of 91·37 per cent of nitrogen and 8·63 per cent. of carbonic acid. It seems probable that the low carbonic acid percentage in this case was due to the fact that the stopping from behind which the sample was taken was only a temporary brattice erected in a return air-way for the purposes of the experiments. As the pit was a wet one, a large proportion of the carbonic acid was most probably absorbed by the water, which would take some time to become saturated, and would thus alter the composition of the first black-damp coming in contact with it.

*A short paper by one of us on the nature and physiological action of black-damp was read before the Royal Society, on January 26th, 1895. For convenience sake we have repeated here a few of the most important data contained in that paper.

TABLE I.

COMPONENT GASES.		Podmore Hall Colliery, Stopping in No. 4 Pit.	Same Stopping, two months later.	Another Temporary Stopping in same Pit.	Half-way down Dip in Forge Ironstone Pit, Apedale.	Stopping in Nabb Pit, Lilleshall Colliery, Two-foot Seam.	Sladderhill Pit, Apedale, Old Banbury Seven-foot Level.	Same Level, further in.	Sladderhill Pit, Five-foot Level.
Composition of the sample	Oxygen	1·45	0·72	5·59	10·07 10·09*	9·60	13·66 13·67*	13·22	13·60
	Nitrogen... ...	82·56	80·78	83·52	82·30	83·08	78·97	79·00	80·68
	Carbonic acid	10·64 10·64*	11·03	5·91 5·88*	7·64 7·60*	7·32	4·49 4·49*	4·80 4·79*	4·81 4·83*
	Marsh-gas ...	5·35	7·47	4·99	0·00	0·00	2·88	2·98	0·90
		100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Composition in terms of air, black-damp, and marsh-gas	Air: Oxygen	1·45	0·72	5·59	10·08	9·60	13·66	13·22	13·60
	Air: Nitrogen... ...	5·49 } 6·94	2·72 } 3·44	21·15 } 26·75	38·14 } 48·23	36·33 } 45·94	51·68 } 65·36	50·01 } 63·25	51·45 } 65·07
	Air: Carbonic acid ...	0·00	0·00	0·01	0·01	0·01	0·02	0·02	0·02
	Black-damp: Nitrogen ...	77·07 } 87·71	78·06 } 89·09	62·37 } 68·26	44·16 } 51·77	46·75 } 54·06	27·29 } 31·76	28·99 } 33·77	29·23 } 34·03
	Black-damp: Carbonic acid ...	10·64	11·03	5·89	7·61	7·31	4·47	4·78	4·80
	Marsh-gas ...	5·35	7·47	4·99	0·00	0·00	2·88	2·98	0·90
		100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Calculated specific gravity of sample ...		1·0106	1·0030	0·9913	1·0274	1·0258†	1·0029	1·0037	1·0129
Calculated composition of the pure black-damp ...	Nitrogen... ...	87·87	87·65	91·37	85·30	86·48	85·86	85·85	85·90
	Carbonic acid ...	12·13	12·35	8·63	14·70	13·52	14·14	14·15	14·10
		100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Calculated specific gravity of the pure black-damp		1·0390	1·0403	1·0196	1·0534	1·0468	1·0502	1·0502	1·0500

* Duplicate determination. † A direct determination gave 1·0252.

Table I. farther shows that the specific gravity of undiluted black-damp is only about 4 to 5 per cent. higher than that of air. Black-damp as actually met with may, moreover, be lighter than air, in consequence of admixture with fire-damp. Such admixture, unless in considerable quantity (10 per cent. or more), will probably not be detected with an ordinary oil-lamp. The flame will simply be extinguished without previously showing a distinct cap.

Origin and Distribution of Black-damp.

Two theories may be advanced to account for the presence of black-damp in mines:—1. That the formation of black-damp is due to the oxidation of coal or associated strata. 2. That black-damp is evolved from the coal or associated strata.

It is well known that coal at ordinary temperatures is liable to a process of slow oxidation in presence of air. This oxidation may even become so rapid as to give rise to evident heating of the coal, and finally to the actual burning which occurs in gob-fires or in coal stacked in large heaps or in the holds of vessels. From its composition, black-damp (such as we examined) seems to be nothing but the residual gas left by this process of slow oxidation at ordinary temperatures.

The most readily oxidizable constituent of coal is the material that gives rise to the gases which constitute ordinary coal-gas. This material consists essentially of about one atom of carbon to three or four of hydrogen. Now, the oxidation of such material in air would leave a residual gas corresponding very closely in composition with black-damp. Nearly half of the oxygen of the air would combine with the hydrogen of the coal to form water, and the other half would go to form carbonic acid. This, together with the residual nitrogen, would form a gaseous mixture, consisting of nitrogen containing 12 to 15 per cent. of carbonic acid. In this process there would be a diminution of about 10 per cent. in the volume of the air, in consequence of the absorption of the oxygen to form water.

A good many additional reasons may be brought forward in support of the view just stated. In the first place, black-damp does not issue at high pressure from fresh coal in the same way as fire-damp*; and coal, which has had ample time to drain off all its gases, may still continue for months

* Although this statement is, so far as we are aware, true for mines in this country, yet a case in France is recorded, in which a gas, believed to be carbonic acid, issued in the form of a sudden outburst, at high pressure. (*Trans. Fed. Inst. of Mining Engineers*, vol. v., page 564.)

and years to produce black-damp. Farther, when black-damp issues from goaves or other cavities it appears to do so either in consequence of a fall in barometric pressure, or simply in virtue of suction from the return air-ways. A goaf which is absolutely sealed off in a fiery seam will probably fill up entirely with fire-damp, even although as long as a little air was admitted large quantities of black-damp may have been present in the same place.

If this view of the formation of black-damp be correct, one would expect to find it always present in return-air, and one would also expect that the proportion of black-damp to fire-damp would increase from the face to the upcast shaft, in consequence of the return-air ventilating districts from which the fire-damp is already drained off, but which still continue to form black-damp.

To test these points we have made several analyses of the air in main return air-ways and at the face, and of fire-damp issuing at the face. The results are given in Table II. on the following page.

It will be seen from Table II. that in all the cases there was present in the return-air as an impurity a mixture of nitrogen and carbonic acid, in addition to marsh-gas. This mixture varied somewhat in composition in the three specimens, but if an average be taken its composition is 86·2 per cent. of nitrogen and 13·8 per cent. of carbonic acid, or almost exactly the mean composition of black-damp. The variations from this mean are probably in part apparent, as an error of analysis, however small, will appreciably affect the result. Real variations may be due to differences in diffusibility and solubility in water, between carbonic acid and other gases. In the case of the Minnie pit we calculated that the respiration of men and horses and the burning of lamps would not affect the return-air to an extent appreciable by the method of gas analysis employed.

Table II. also shows that from the surface to the upcast shaft there was an increase in the proportion of nitrogen and carbonic acid present as impurities relatively to the marsh-gas. In the fire-damp issuing from a borehole the proportion was about 1 to 7; in a heading in process of being driven through the whole coal the proportion was as 1 to 3, and in the main return air-way 1 to 0·6. These observations therefore confirm the idea that the black-damp was not given off from the coal, but was simply the residual gas left on oxidation of coal by air.

Whether or not oxidation is capable of accounting for the whole of the black-damp or extinctive-gas met with in some mines is a question which requires farther investigation.

TABLE II.

Component Gases.		Fire-damp from Pipe inserted into Coal, Minnie Pit, Podmore Hall.		Air from Heading near where last Sample taken,* Dec. 19th, 1894.		Air from Main Return, Minnie Pit, close to Upcast Shaft,† Dec. 19th, 1894.		From Brown's Crut (Return), close to Main Return,‡ Jan. 5th, 1895.		From Main Return, No. 4 Pit, Podmore, close to Upcast Shaft.	
	Oxygen	0·1		19·85		20·30		20·26		20·31	
	Nitrogen	9·4		76·00		78·405		77·64		78·735	
	Carbonic acid	4·1		0·43 0·43§		0·20 0·19§		0·28 0·26§ 0·28§		0·30 0·31§	
	Marsh-gas	86·4		3·72		1·10		1·84 1·82§		0·65	
		100·0		100·00		100·00		100·00		100·00	
Composition in terms of air and impurities	Air: Oxygen	0·1		19·85		20·30		20·26		20·31	
	Air: Nitrogen	0·4	0·5	75·10	94·98	76·80	97·13	76·65	96·94	76·84	97·18
	Air: Carbonic acid	0·0		0·03		0·03		0·03		0·03	
	Nitrogen	9·0		0·90		1·605		0·99		1·895	
	Carbonic acid	4·1	13·1	0·40	1·30	0·165	1·77	0·24	1·23	0·275	2·17
	Marsh-gas	86·4		3·72		1·10		1·83		0·65	
		100·0		100·00		100·00		100·00		100·00	
Calculated composition of the black-damp (or mixture of nitrogen and carbonic acid) present as impurity ...	Nitrogen...	68·7		69·2		90·7		80·5		87·3	
	Carbonic acid	31·3		30·8		9·3		19·5		12·7	
		100·0		100·0		100·0		100·0		100·0	

* This heading had been fenced off, and no work had been done in it for several days. † Slight cap just noticeable.
‡ Distinct cap, estimated as $\frac{1}{16}$ inch above flame. § Duplicate analysis.

It is noticeable that the fire-damp collected in the Minnie pit contains an unusually high percentage of carbonic acid. Apparently a small quantity of carbonic acid was given off from the coal along with the marsh-gas, just as happens in the manufacture of coal-gas for lighting purposes. The nitrogen and part of the carbonic acid of the fire-damp were probably formed at the expense of air which had penetrated into and oxidized the coal.

Physiological Action of Black-damp.

We have had numerous opportunities of observing on ourselves the symptoms produced by black-damp. The observations were made partly while we gradually advanced into increasing proportions of black-damp, partly in chambers made by erecting a brattice or door in front of a stopping and allowed gradually to fill with black-damp after opening the tap in an iron pipe passed through the stopping, partly by simply inspiring the black-damp issuing from a pipe, and expiring through the nose.

The first distinctly perceptible effect of breathing a gradually increasing proportion of black-damp is deepening of the respirations. This effect is not perceptible until the air is contaminated considerably beyond the point at which an oil-lamp ceases to burn. As will be seen by comparing Tables III. and IV., about 15 to 19 per cent. of black-damp renders an atmosphere extinctive to oil-lamps or candles, while 26 to 27 per cent. is requisite to just affect the breathing.

If the proportion of black-damp be increased a little farther the respirations become more frequent as well as deeper. With still farther increase there is marked panting, similar in every way to that caused by running. With about 50 to 55 per cent. the panting is very violent, and accompanied by marked distress. There may also be throbbing and headache felt over the brow, which is often increased for two or three minutes on returning to the fresh air. As a rule, the face is flushed. After continuing to breathe this atmosphere for a minute or two the distress is not so great as at first. About this point the face begins to be slightly bluish, and with a still farther increase the colour gradually becomes leaden blue. On returning to fresh air the leaden blue is suddenly replaced by the natural colour. The change is particularly evident at the lips and ears. The appearance of the leaden-blue colour is a sign of imminent risk of loss of power over the limbs or of loss of sensation. This danger-point is reached with about 60 per cent. of black-damp.

The effects observed on breathing the almost undiluted black-damp from the first stopping (Table I.) in No. 4 Podmore Hall pit, were as

follows:—After the first two or three respirations there was marked panting, which rapidly increased. After about 20 seconds the face became leaden blue, and the pulse increased in frequency. After about 30 seconds, there was confusion of mind, so that the observations could not be continued. On breathing fresh air again, recovery was almost instantaneous. A mouse exposed to the same air became unconscious, and went into convulsions within 15 seconds. It was all but dead before it could be snatched away and restored to the fresh air.

We never experienced any after-effects from breathing black-damp, even when we had been for a considerable time in an atmosphere which instantly extinguished a lamp.

The increased depth and frequency of the respirations, together with the flushing and frontal headache, are undoubtedly caused by the carbonic acid present in the black-damp. As will be seen from Table III., the respirations begin to be affected when the oxygen percentage has fallen to about 15 per cent., and the carbonic acid has risen to about 3¼ to 3½ per cent. Now, a fall to 15 per cent. in the oxygen percentage does not of itself sensibly affect the respirations, or produce any other evident symptom;* but about 3½ per cent. of carbonic acid is just the amount required to produce a sensible increase in depth of the breathing. Until blueness of the face appears all the symptoms agree with those produced by corresponding mixtures of carbonic acid with air or oxygen.† The blueness is due to there being an insufficient percentage of oxygen to saturate the red corpuscles of the blood as they pass through the lungs; and after this point is reached, symptoms due to lack of oxygen begin to predominate. Confusion of mind, loss of power, and other dangerous symptoms are caused by want of oxygen; and death, when it occurs, is certainly due to the same cause. The danger-point from deficiency of oxygen is reached somewhat suddenly, whereas with carbonic acid it is reached through stages of gradually increasing distress. It is fortunate that there is present in black-damp sufficient carbonic acid to give warning of the impending danger from deficiency of oxygen.

Marsh-gas when present along with black-damp acts precisely like nitrogen. It helps to reduce the oxygen, but has no direct action of its own like that of carbonic acid. That this is actually the case was proved by special experiment. We found that breathing for five minutes the contents of a bag filled with a mixture of 20 per cent. of oxygen and 80

* Messrs. Haldane and Lorrain Smith, *loc. cit.*

† Messrs. Haldane and Lorrain Smith, *loc. cit.*, page 177. Some very erroneous statements as to the action of carbonic acid are unfortunately still current.

TABLE III.

Component Gases.	Points at which Breathing became noticeably Deeper.		Points at which Panting was very Severe.		
	Nabb Pit, Lilleshall Colliery.	No. 4 Pit, Podmore Hall Colliery.	Nabb Pit, Lilleshall Colliery.	No. 4 Pit, Podmore Hall Colliery.	Dip in Forge Pit, Apedale.
Oxygen	15·30	14·84	9·60	10·11	10·08
Nitrogen	81·32	79·26	83·08	79·72	82·30
Carbonic acid	3·38	3·26	7·32	6·01	7·62
Marsh-gas	0·00	2·64	0·00	4·16	0·00
	100·00	100·00	100·00	100·00	100·00
Percentage of black-damp	26·79	26·36	54·07	47·47	51·77

TABLE IV.

Component Gases.	Nabb Pit, Lilleshall Colliery.			Forge Pit, Apedale.	No. 4 Pit, Podmore Hall Colliery.		
	Upright Candle Extinguished.	Safety Lamp (bonneted Clanny) Extinguished.	Horizontally-placed Candle Extinguished.	Hydrogen Flame Extinguished.	Oil Lamp (bonneted Clanny) Extinguished.	Hydrogen Flame about Doubled in Height.	Hydrogen Flame Extinguished.
Oxygen	17·64	17·23	17·05	10·08	16·43	14·84	11·41
Nitrogen...	80·15	80·19	81·33	82·30	79·25	79·26	79·53
Carbonic acid	2·21	2·58	2·62	7·62	2·49	3·26	5·37
Marsh-gas	0·00	0·00	0·00	0·00	1·83	2·64	3·69
	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Percentage of black-damp	15·60	17·56	18·42	51·77	19·56	26·36	41·72

per cent. of fire-damp produced no symptoms, and a mouse placed in the same mixture for three-quarters of an hour was also quite unaffected.

We could never discover in black-damp or fire-damp any trace of carbonic oxide.

4.—Action of Black-damp on Lights.

The results of a series of observations on the action of black-damp on lights are given in Table IV. on the preceding page.

In the observations made in the chamber in front of a stopping at the Nabb pit, Lilleshall colliery, a safety-lamp and two naked candles were placed at the same level and close together in the chamber, in which black-damp accumulated very slowly when the tap was opened and the brattice closed. One of the candles was fixed in a vertical and one in a horizontal position. A sample of air was taken close to, and at the level of, each light at the moment of extinction. The first three columns show the results of the analyses.

The fourth column shows the point at which a Clowes hydrogen-lamp was extinguished when we slowly advanced, with the hydrogen flame burning, down a dip of about 1 in 3 in the Forge ironstone pit at Apedale. At the point where the hydrogen went out, there was severe respiratory distress, accompanied by blueness of the face, and a tendency to giddiness in one of us. Previous to extinction, the flame had increased in size from 0·4 to 1·4 inches, and had become very blue. It went out suddenly.

The last three columns give the results of observations made in the chamber in front of the stopping in No. 4 pit, Podmore Hall colliery. In this case the black-damp was mixed with fire-damp, and accumulated in the chamber more rapidly than in the Nabb pit. From a comparison of the results with those in the other pits it would seem that the admixture of marsh-gas had the effect of somewhat retarding the extinction of the oil-flame, and hastening the extinction of the hydrogen.

The action of black-damp in extinguishing lights is what one would expect from its composition and from ascertained facts with regard to other extinctive atmospheres. The most complete series of experiments on extinctive atmospheres are those of Dr. Clowes.* He finds that air becomes extinctive to candles and lamps when diluted with nitrogen until the oxygen percentage has fallen to about 16·4 per cent. This is a slightly lower percentage than that indicated by our experiments, but the difference is explained by the fact that Dr. Clowes determined the

* *Proceedings of the Royal Society*, 1894, vol. lvi., page 2.

point at which lights are immediately extinguished, whereas our results refer to the point at which they are gradually extinguished. Gradual extinction is known to occur at a somewhat higher oxygen percentage than immediate extinction.*

INFLUENCE OF BLACK-DAMP ON THE EXPLOSIBILITY OF FIRE-DAMP.

Since black-damp and fire-damp occur so commonly together, whether in return-air, goaves, or elsewhere, it seemed of importance to make some experiments on the influence which it exerts on the explosibility of fire-damp. Our experiments were conducted as follows:—Three large oil-cans were filled respectively with air, black-damp (from the first stopping in No. 4 pit, Podmore), and fire-damp (from a bore-hole in the Minnie pit). Each oil-can was provided with a tightly-fitting cork, through which passed two glass tubes. Through one of these tubes water was allowed to flow in at any required rate, the gas being thus expelled through the other tube, which was connected with a small experimental gas-meter. After passing the meter, the gas from each oil-can was conducted through another piece of tubing to one of the branches of a four-way tube. From the fourth branch, the mixed gases were conducted through tubing and a tubulated cork into the upper part of a wide glass tube (a lamp-chimney) fixed in a vertical position. As the mixture was always lighter than air, the lamp-chimney was always filled with it, while the excess escaped by the lower opening. By inserting the flame of a candle or a jet of hydrogen into the lamp-chimney, it was possible to ascertain whether the mixture was explosive or extinctive. After each test, an interval was left, sufficient to allow of the chimney becoming cleared of the products of combustion.

The black-damp employed contained 7·47 per cent. of marsh-gas, while the fire-damp contained 14 per cent. of nitrogen and carbonic acid, together with 5 per cent. of air, which latter was found on analysis to have leaked in while the oil-can was being filled. The results of the experiments are shewn in Table V. The third column gives the actual percentages of marsh-gas, black-damp (nitrogen and carbonic acid), and air at each test.

Two important conclusions may be drawn from the experiments shown in Table V.:—(1) A mixture of black-damp and fire-damp may, when largely diluted with air, be extinctive to lamps and not explosive, but may become explosive when less diluted. This fact comes out clearly on comparing experiments Nos. 1 and 2, 4 and 5, 6 and 7, and 8 to 14.

* Dr. Angus Smith, *Air and Rain*, page 159.

TABLE V.—EXPERIMENTS WITH MIXTURES OF FIRE-DAMP, BLACK-DAMP, AND AIR.

Component Gases.	Time for Passage of Half-litre.	Amount passing per Minute.	Corrected for Fire-damp in Black-damp, etc.	Percentage Composition.	Observations.
1.	Min. Sec.	Litres.	Litres.		
Fire-damp ...	2 30	0·200	0·249	4·88	Extinguished light.
Black-damp ...	0 26	1·154	1·095	21·45	
Air	0 8	3·750	3·760	73·67	
		5·104	5·104	100·00	
2.					
Fire-damp ...	2 30	0·200	0·249	7·98	Inflammable.
Black-damp ...	0 26	1·154	1·095	35·11	
Air	0 17	1·765	1·775	56·91	
		3·119	3·119	100·00	
3.					
Fire-damp ...	2 48	0·179	0·231	7·46	Slightly inflammable, and burned outside tube.
Black-damp ...	0 26	1·154	1·092	35·26	
Air	0 17	1·765	1·774	57·28	
		3·098	3·097	100·00	
4.					
Fire-damp ...	2 28	0·203	0·251	6·85	Inflammable; flame went right up tube.
Black-damp ...	0 26	1·154	1·095	29·89	
Air	0 13	2·308	2·318	63·26	
		3·665	3·664	100·00	
5.					
Fire-damp ...	2 28	0·203	0·251	5·76	Flame enlarged, and then went out. Air-current stopped during this experiment.
Black-damp ...	0 26	1·154	1·095	25·14	
Air	0 10	3·000	3·010	69·10	
		4·357	4·356	100·00	
6.					
Fire-damp ...	2 30	0·200	0·249	4·88	Flame enlarged, waved about, and went out. Hydrogen flame enlarged, and turned blue; long cap.
Black-damp ...	0 26	1·154	1·095	21·45	
Air	0 8	3·750	3·760	73·67	
		5·104	5·104	100·00	
7.					
Fire-damp ...	2 30	0·200	0 249	6·46	Inflammable; flame went to top of tube.
Black-damp ...	0 26	1·154	1·095	28·41	
Air	0 12	2·500	2·510	65·13	
		3·854	3·854	100·00	
8.					
Fire-damp ...	2 30	0·200	0·287	6·88	Partly inflammable; flame went up tube sometimes nearly to top by candle. With hydrogen flame the mixture seemed more inflammable.
Black-damp ...	0 18	1·666	1·569	37·59	
Air	0 13	2·308	2·318	55·53	
		4·174	4·174	100·00	

TABLE V.—*Continued.*

Component Gases.	Time for Passage of Half-litre.		Amount passing per Minute.	Corrected for Fire-damp in Black-damp, etc.	Per-centage Composition.	Observations.
	Min.	Sec.	Litres.	Litres.		
9.						
Fire-damp ...	2	30	0·200	0·287	5·11	Candle extinguished at once. Hydrogen flame enlarged; long cap; then went out.
Black-damp...	0	18	1·666	1·569	27·94	
Air	0	8	3·750	3·760	66·95	
			5·616	5·616	100·00	
10.						
Fire-damp ...	2	30	0·200	0·287	5·11	Candle went out at once.
Black-damp...	0	18	1·666	1·569	27·94	
Air	0	8	3·750	3·760	66·95	
			5·616	5·616	100·00	
11.						
Fire-damp ...	2	30	0·200	0·287	6·25	Inflammable or explosive.
Black-damp...	0	18	1·666	1·569	34·16	
Air	0	11	2·727	2·737	59·59	
			4·593	4·593	100·00	
12.						
Fire-damp ...	2	30	0·200	0·287	7·43	Slightly inflammable; flame went about half-way up tube.
Black-damp...	0	18	1·666	1·569	40·58	
Air	0	15	2·000	2·010	51·99	
			3·866	3·866	100·00	
13.						
Fire-damp ...	2	30	0·200	0·287	6·57	Explosive; flame went quickly half-way up tube.
Black-damp...	0	18	1·666	1·569	35·94	
Air	0	12	2·500	2·510	57·49	
			4·366	4·366	100·00	
14.						
Fire-damp ...	2	30	0·200	0·287	5·11	Candle flame waved about, and went out; no explosion. Hydrogen flame enlarged; long cap.
Black-damp...	0	18	1·666	1·569	27·94	
Air	0	8	3·750	3·760	66·95	
			5·616	5·616	100·00	
15.						
Fire-damp ...	—		0·000	0·125	2·31	Candle went out more quickly, and flame did not wave about so much as in last experiment.
Black-damp...	0	18	1·666	1·541	28·45	
Air	0	8	3·750	3·750	69·24	
			5·416	5·416	100·00	

(2) A mixture containing air and 6 per cent. of marsh-gas is still explosive in spite of the presence in it of even a third of its volume of black-damp. This is shown most clearly in experiment No. 11.

The presence of black-damp, in a mixture of fire-damp and air, has thus little or no influence on the explosibility of the mixture, provided that sufficient oxygen is present for the complete combustion of the fire-damp. If, however, the oxygen is insufficient, as in experiments Nos. 8 and 12 (in each of which there were less than two volumes of oxygen to one of marsh-gas), the explosibility of the mixture is of course diminished by the black-damp.

In the working of a coal-mine conditions must not infrequently occur in which a knowledge of the above facts would be of importance. The gas from a goaf may, for instance, be extinctive to flame when largely diluted with air, and yet become explosive when less diluted. Black-damp containing from about 13 to 30 per cent. of marsh-gas would possess this property. In the case of interference with the ventilation of a pit the return-air might easily become first extinctive and then explosive. Supposing, for example, that the air passing through No. 4 pit, Podmore Hall, was largely diminished in amount, the percentages of black-damp and fire-damp in the return air would increase simultaneously and in the relative proportions (1 of fire-damp to 2·3 of black-damp) in which they are present under ordinary circumstances (see Table II.). Now, this air would not become explosive until about 6 per cent. of fire-damp was present, at which point there would also be 20 per cent. of black-damp, so that the oxygen percentage would be reduced to 15·4. Before this point was reached, however, the air would have become extinctive to lights. In the Minnie pit of the same colliery the return-air would become explosive previously to becoming extinctive, were the ventilation correspondingly reduced. It is probable that in many districts, the return-air usually contains so small a proportion (less than 1 to 8) of fire-damp in relation to black-damp as to prevent such air from becoming explosive, however much the ventilation might be reduced.

The PRESIDENT said that although his name appeared as joint author with Dr. Haldane of this paper, it was due to Dr. Haldane to state that his (the President's) part in the investigation was comparatively unimportant, and that he acted as Dr. Haldane's assistant rather than as a collaborator. It was a pleasure to assist Dr. Haldane, who was most indefatigable in his endeavours, and spared no pains to make the investigation as complete as possible. One of the most interesting results obtained was recorded in Table I., showing that all the samples of black-damp analysed were composed chiefly of nitrogen, whereas black-damp was usually

described as consisting chiefly or entirely of carbonic acid gas, but he had not been able to find any previous analyses on which this opinion could be based. Another interesting question on which he would like to hear the opinions or experience of members was regarding the formation or evolution of black-damp in mines. Particularly, as to whether the slow oxidation of carbonaceous substances by the atmospheric air was sufficient to account for the presence of black-damp in all mines or whether it pre-existed in the coal or accompanying strata, and was evolved therefrom on exposure.

Mr. T. L. ELWEN (Durham) wrote that he understood the samples in Table I. were taken in each case from a space which had previously been filled with air, whose presence was shown by the proportion of air in each sample, a greater number being taken from exposed levels than from behind stoppings. The sample of gas taken from the solid coal (Table II.) showed the presence of less black-damp, but was not this decrease accounted for by the law of transpiration of gases, the relative velocities of which are for carbonic acid 1·370, and marsh gas 1·815.* In consequence, the carbonic acid gas would lag behind, and whilst showing a small proportion in a sample taken from the freshly-cut face, would show itself more prominently in a sample taken either after putting in a stopping or from an unventilated dip-level. This fact favoured the theory that black-damp was evolved from the coal and associated strata. The same seam which yielded black-damp at a small depth was often noted for its richness in fire-damp at a greater depth, the latter gas, owing to its lightness, having escaped through the crevices of the strata in a shallow mine to the surface, leaving an abundance of black-damp. It will have been the experience of many who have worked shallow mines, that great difficulty was experienced in opening out and working a new seam or district, due to the large quantity of black-damp continually pouring out of the newly-cut coal and joints in the strata, like scores of small blowers which become spent in a few days. This issue occurred in spite of the fact that a large quantity of water was constantly traversing the strata and absorbing the carbonic acid gas in its course, at any rate in that part of the strata which laid above the water-level or drainage-line of the district. This could not be due at the time to oxidation of the coal, although it might be due to the slow oxidation going on previously during the conversion of the coal.

Mr. W. C. BLACKETT (Durham) said that the results read by Dr. Haldane showed that there was very little difference between the forma-

* *Miller's Elements of Chemistry.* Sixth Edition, 1877, Part I., page 116.

tion of black-damp as suspected, and almost proved by themselves, and black-damp as it would be formed by cutting off all access of air to that room. It seemed to him that by the time they had reached that interesting point where their lips began to turn blue they should have formed as good a sample of black-damp in the room as could be found, and it would be formed on similar lines to those suggested by the authors in their paper. It was perhaps interesting to look at it from that point of view, on calling up thoughts as to how long men would live in air when shut up in a mine. It was quite evident that they would live longer than had been hitherto expected, and a great deal longer than their lights would continue to burn. An interesting point which had not been mentioned was that there was a lamp which, in his experience of mines wherein black-damp occurred, he found to burn very much longer than the ordinary candle or the ordinary lamp, that is a lamp in which petroleum spirit was burnt. He had found that workmen could use that lamp in a mixture of black-damp and air, where it was difficult for heavier oils to burn.

Mr. W. Spencer (Leicester) said that he had listened to a very interesting paper, and thought that the members should feel indebted to anyone who tried to experiment on himself voluntarily. He had more than once made a similar experiment involuntarily. In one case, all the lights of a party (of four or five) were extinguished by black-damp, but they groped their way into fresh air and felt no worse for it. In another case, some were very sick for some time, but that was in after-damp. The great thing was to get out of the way of such gases as soon as possible. It was well known that men have worked for a long period with their candles in a horizontal position to keep them alight, so that black-damp could not be so injurious to health as was generally imagined.

Mr. J. Barrowman (Hamilton, N.B.) asked whether the depth of the mine had anything to do with the prevalence of black-damp or fire-damp? In Scotland, he had found that black-damp, exuding from the strata, was most abundant in workings near the surface, and that in the same districts, as deeper workings were opened up, fire-damp was found.

Mr. A. H. Stokes (Derby) said in his younger days he was taught that black-damp was carbonic acid gas, but it appeared that this was not so. In fact any noxious gas found in the mine appeared to be called black-damp, except fire-damp. In Table V., experiments Nos. 10 and 14, the results were both exactly alike, but these were two different observations. He also noticed on page 561 that a mixture of air and 6 per cent. of fire-damp was still explosive when mixed with one-third of its volume of black-damp.

Dr. HALDANE, interposing, said that the mixture used consisted of 100 parts—6 of fire-damp, 33⅓ of black-damp, and the rest air.

Mr. STOKES, continuing, said that the paper did not explain whether the reduction was in the 6 per cent. of fire-damp or in the volume of air. It now appeared that there was a reduction of air, which made a material difference with regard to its explosive properties. Mr. Blackett stated that the petroleum spirit-lamp would burn in black-damp much better than any other lamp. Personally, he liked a lamp that would indicate the presence of black-damp as soon as possible. He did not think that there was any advantage in having a lamp to see how far one could go into black-damp without knowing it. The best thing was to have a lamp which showed the smallest percentage, and, when found, make your way as quickly as possible to the bottom of the downcast shaft.

Mr. W. C. BLACKETT said he had neither commended nor condemned any lamp, but had only drawn attention to a fact. It had certainly been his experience that shallow mines were the chief mines where black-damp was found. That fact seemed to support the theory of the action of the air, because it was only in shallow seams that air could have natural access to the pores or crevices of the coal. At greater depths the air could not reach the coal, and it was also excluded by the pressure principally of the fire-damp which existed, and that might be the reason why black-damp was found in shallow mines and not in deep mines.

Mr. GERRARD (Manchester) remarked that no mention was made in the paper of the effect of continued working in places where black-damp prevailed. Experience had proved that such working was very injurious. It was highly important to know the momentary effect of such gases, and especially to learn the composition of that which had been hitherto known as black-damp, but workers should not be encouraged to continue or to remain in such atmospheres.

The PRESIDENT said that his experience agreed with Mr. Barrowman's, that black-damp was chiefly found in shallow mines. Mr. Blackett seemed to draw the conclusion that it was the opinion of both writers of the paper that black-damp was formed by oxidation. His opinion hitherto had been that black-damp was evolved from the coal, and he could not say that he was as yet prepared to abandon that opinion, although black-damp might also be formed by oxidation of the coal by air. With regard to Mr. Gerrard's remarks about continuous working in black-damp, he preferred to take Mr. Stokes' view that the best thing to do was to get out of it as quickly as possible.

Mr. A. HASSAM (Stoke-upon-Trent) thought that the theory of oxidation did not account for the presence of black-damp in ironstone-mines. With one exception the samples referred to in the paper were taken in coal-mines and not in ironstone-mines. So far as his experience went, he had found more black-damp in ironstone-mines than in coal-mines. Its presence could not be due to oxidation in these cases. There had been recently a large outburst of carbonic acid in a French mine which destroyed a number of the workmen.*

Mr. BLACKETT said that he only suggested the explanation as it fell in with the theory of the authors that the atmosphere had been or was able to penetrate more easily to shallow seams than to those at greater depths, and of course oxidation would necessarily take place.

Mr. W. STATHAM (Chesterton) said that he had known a case where there had been fire-damp and black-damp given off alternately from the solid face of ironstone, at a depth of about 1,000 feet.

Mr. J. LINDOP (Walsall) did not think that black-damp was always evolved from coal-mines. It was found in deep wells where there were no coal-seams. He had had an involuntary experience of black-damp when he was a young man, and worked in the pits. It seemed to be then the practice to see how little they could ventilate the pits, and the workmen had sometimes to work with two or three candles placed together in a horizontal position. There was no doubt about its being injurious to health to work in black-damp. Dr. Haldane probably was not in it long enough, or else he would have had a different experience from that which he described. The head would be giddy, and the limbs would ache as though one had rheumatic fever, if one stayed in it long enough. He could assure the members that black-damp was very injurious to health.

Dr. HALDANE, in reply, said that so many points had been raised in the course of this discussion that there was hardly time to refer to them all. Mr. Stokes asked what was the composition of black-damp if it was not carbonic acid gas. An average composition was a mixture of 86 per cent. of nitrogen and 14 per cent. of carbonic acid gas. Of course it was possible that there might be, in other pits in other districts, some gas ordinarily believed to be black-damp, but really of a different composition. The experience recorded in the paper tended to show that the composition of black-damp was perfectly definite. As regards the continuous effects of black-damp and carbonic acid, he must confess that he had no great experience in that matter. He had never been in black-damp for more than an hour or so at a time. The experience of others

* *Trans. Fed. Inst.*, vol. v., page 564.

would be much more valuable than any ideas which he held upon the subject. In conjunction with Dr. Lorrain Smith, he had made laboratory experiments with noxious air, not with the black-damp of pits, but the noxious mixture produced when air was vitiated by respiration. The effect of remaining for some hours in air thus vitiated so that a candle would not burn was very slight. He found that rabbits kept in air vitiated to this extent lived for a fortnight, throve uncommonly well, and increased in weight. As regards the evolution of carbonic acid gas from the strata, there were occasionally recorded cases. His attention had been drawn to a case in France. The gas was not analysed, but it seemed very likely that it was pure carbonic acid gas. That opinion was held at the place, and it seemed to be the most probable one. In conclusion, he wished to say that none of the work described in the paper could have been carried out but for the President, who had not only arranged for the experiments being made, but had actively co-operated from beginning to end in carrying them out.

Mr. W. Spencer moved a vote of thanks to Messrs. Haldane and Atkinson for their valuable paper.

Mr. J. Gerrard seconded the motion, which was agreed to.

The following paper by Mr. Edmund Spargo on "Lithographic Stone and its Uses" was taken as read :—

LITHOGRAPHIC STONE AND ITS USES.

By EDMUND SPARGO.

Lithography belongs perhaps more to the arts of taste and design than to productive manufactures, but in order to indicate the importance and extent of the demand, and the quarrying and preparation for use of good lithographic stone, a few descriptive observations on lithography are necessary. Notwithstanding the heading of this paper, the writer will consequently commence with the discovery of the art of lithography. Few persons outside of those interested either in the quarrying, preparation for the market, sale, or use of lithographic stone, have any knowledge of its industrial importance, or of the large number of persons engaged upon it, from the labourer employed at the quarries, including those occupied in preparing the stone for use, to the artists engaged in the design and preparation of the finest drawings, prints, and other writings, finished by the aid of lithographic stone.

The term lithography is derived from the Greek language (*lithos*, a stone, and *graphein*, to write), and designates the art of printing or placing of impressions upon paper of figures, drawings, and writing previously traced upon the stone. Lithography constitutes one of the most interesting and important reproductive arts.

Lithography was invented by Aloys Senefelder, at Munich, in 1796, and in the same year a piece of music (Senefelder's first work) was printed from stone. Four years afterwards Senefelder patented his invention in Bavaria, Austria, and most of the German states. Afterwards he opened establishments in London and Paris, but does not seem to have succeeded very rapidly, and it was not until many years afterwards that the then complicated manipulation of lithography (through the great secrecy and jealousy with which the invention was guarded) became sufficiently known and simplified for the rapid advance in the process which followed.

Senefelder, on whom the King of Bavaria settled a pension, lived, however, to see his invention brought to practical perfection.

The processes of lithography were founded upon:—

(1) The strong adhesion of greasy substances to smoothly polished fine-textured calcareous stone, the encaustic matter forming the lines or traces;

(2) Upon the power acquired by the parts of the stone penetrated by the encaustic substance, of attracting to themselves the printing inks employed;

(3) The affinity of one greasy body to another, and their antipathy to water;

(4) The facility with which calcareous stone imbibed water in all parts of the surface of the stone not impregnated with the encaustic;

(5) Lastly, by the application of the lithographic press to the stone of sufficient pressure to transfer to paper the ink which covered the greasy tracings of the encaustic, thus producing the design or writing.

As almost any encaustic matter would easily penetrate the surface of a calcareous stone, it naturally followed that if a greasy line be drawn over a prepared limestone, its adhesion was such that it could only be erased by entirely rubbing down the surface of the stone so far as the grease had penetrated. If water be washed over the stone it remained only on the parts not covered with grease; if a roller charged with lithographic-greasy-ink be then passed over the surface of the stone, the ink would be found adhering to the greasy traced portions only, while the parts wetted with water would repel the ink and remained clean, and with the requisite pressure the greasy ink-tracings were transferred to paper.

Amongst the various methods employed in lithography are drawing on stone with pen or brush, with liquid ink, drawing on prepared paper and transferring to stone, transferring from type-printing, engraved copper, steel and zinc plates, woodcuts, and the reproduction of drawings by photo-lithography, etc.

Drawing on prepared paper and transferring to stone is perhaps the method most largely adopted, but the most interesting and beautiful of all the methods of printing from stone is the process known as chromo-lithography, in which it is often necessary to employ from twenty to thirty separate stones, each of which yields a distinct tint to produce the infinite variety of colours in a finished coloured drawing.

All the methods mentioned and the class of work produced vary only in the manner of applying (and to some extent in the preparation of the encaustic substance) the drawings or writing to the surface of the stone. The printing from them is, more or less, in nearly all cases identical.

The writing and drawing-inks and crayons are composed of lard, hard soap, white wax, shellac, Venetian turpentine, carbonate of soda, and Paris black. The proportions used and the methods of manufacture vary considerably. It is needless to observe that the greasy caustic ingredients constitute the important parts, the black being merely added to enable the draughtsman to see the effect that he is producing as he proceeds.

The foregoing is a brief outline of the principal methods and processes employed in lithography, each of which is capable of an infinite number of variations in the hands of different operators.

Lithographic Stone.

The art of lithography was discovered in the same district as that in which the only suitable stone for the purpose has hitherto been found, or at all events where it has been developed to any appreciable extent, namely, Solenhofen, about 50 miles north of Munich, in Bavaria.

The Solenhofen limestone is found high up in the Jurassic series above the Lias beds, and disposed in layers so thin as to be designated calcareous slate, some of the laminæ being thin enough to be used for roofing purposes. Similar stratifications are somewhat rare and limited in extent, notwithstanding the fact that during at least the last fifty years diligent search has been made for lithographic stone in almost every part of the world. Up to the present time no successful rival to the Solenhofen lithographic stones has been found.

Fifty years ago, the *Montreal Herald* announced that Sir W. Logan (well known for his geological researches in Canada) had discovered near Lake Simcoe, and explored to the extent of 60 or 70 miles, an immense bed of lithographic stone, and stated that, if true, the discovery would prove of great importance to the art.

Three years later, the *Mining Journal* reported that a quarry of good lithographic stone had been discovered on the southern coast of Arabia, and that it was intended to export the stone to India.

In 1848, the French Society for the Encouragement of Arts and Manufactures offered a prize of £60 (1,500 francs) for the discovery and practical working of new quarries of lithographic stone in France, the society being convinced that there existed in many localities of the country places where lithographic stone might be quarried to advantage.

Strenuous efforts have continued to be made in various parts of the world to discover suitable stone for the purposes of lithography. Meanwhile the consumption and demand for the stone have continued to increase, and frequent reports have been published of the discovery of

suitable stone. Hitherto, however, no stone has been discovered under sufficiently favourable circumstances, or in sufficient abundance, and possessing the essential qualities of the better class of the Solenhofen stone to become a successful rival.

Reports have from time to time been published of discoveries of the stone having been made in the neighbourhood of Pappenheim and lower down on the river Danube, and more recently on the river Algetki, near the village of Belakleutch, in the Caucasus. The Algetki stone is found about 30 miles distant from the railway at Tiflis. Small samples of this stone have a striking resemblance, in colour and texture, to some of the best Solenhofen beds.

France, Italy, and Servia claim to have valuable beds of lithographic stone. The only place in the United Kingdom where stone suitable for lithographic purposes has been discovered and worked in appreciable quantities, is near Bath. This stone is found in the White Lias beds, which are immediately below the Blue Lias beds.

The most recent discovery of lithographic stone is located on the north-eastern escarpment of the Privis mountain in Croatia (Austria-Hungary), about 4 miles from the Generalskistal station on the railway from Fiume to Buda-Pesth. The mountain is composed of Carboniferous Limestone disposed in well-defined layers from 4 inches to 3 feet in thickness, of great density, fine grain, and homogeneous texture. Many of the layers are sufficiently free from fossiliferous and other injurious markings and internal joints to afford the finest quality of all requisite-sized lithographic slabs. Each bed displays a distinct colour or tint varying from a whitish-yellow to a dark cream, through smoky dove-colour to dark greyish-blue, the latter description predominating in quantity over the others. The beds are inclined from 35 to 40 degrees to the south, and are found under the most favourable circumstances, not only for the quarrying of the stones in rectangular blocks, but also for their subsequent preparation for the market. There is ample water-power available in the immediate locality for cutting, rubbing, and polishing the blocks (by the aid of suitable machinery) into the requisite thicknesses and dimensions required by the trade. This discovery is looked upon as likely to rapidly develop into a national Croatian industry, and is already causing some excitement in that country.

The writer has noted distinct layers of lithographic stone alternating with ordinary Carboniferous Limestone and marble-beds, in Derbyshire, Anglesey, and Ireland; but, unfortunately, he found that their utility for lithographic purposes was invariably destroyed by the too frequent

occurrence in the beds of fine crystalline veins, which were found to be more indurated than the general body of the stone. Some of the stones also contained too many fossils (shells chiefly), which were much softer than the remainder of the stone, and in addition to these defects the most suitable layers of stone were overlain by a considerable thickness of over-burden and unmerchantable stone.

The Solenhofen Quarries.

The wonderful quarries of Solenhofen have hitherto defied all competition, and have maintained practically an absolute monopoly of the world's supply of lithographic stone, notwithstanding the almost prohibitory prices which lithographers have had to pay for the stone ever since the invention of lithography. There are six distinct quarrying areas, known as Langenaltheim, Mühlheim, Moensheim, Lichtenberg, Solenhofen, and Eichstadt, the areas varying in superficial extent from 1,378 acres (558 hectares) at Solenhofen, to 7,413 acres (3,000 hectares) at Eichstadt. The quarrying-areas embrace in the aggregate 19,170 acres (7,758 hectares), in which 160 quarries are in operation, giving employment to about 1,200 workpeople. The thickness of the workable strata in the aggregate varies from 40 to 60 feet (12 to 16 metres) at the Langenaltheim quarry to 60 or 100 feet (20 to 30 metres) at the Solenhofen quarry.

The following is a general section of the strata exposed in the principal Solenhofen quarries:—

	Feet.
1.—Soil, clay, and siliceous limestone, with numerous fossils of ammonites, etc., about	10
2.—Calcareous marl, from	6 to 7
3.—Limestone, with slaty hornstone, containing ammonites, etc., from	13 to 14
4.—Limestone, rich in small fossils and coccolites, about ...	3
5.—Siliceous limestone, rich in fossils, from	16 to 17
6.—Siliceous limestone, almost devoid of fossils	33
7.—Lithographic stone, commencing with 260 thin laminations and ending with 25 thicker layers	66
8.—Valueless calcareous slaty-beds...	33
9.—Irregular beds of compact massive limestone	16 to 17
10.—Dolomitic formation of unknown thickness.	

It will be observed from the above section that the quarrying operations at Solenhofen have exposed a vertical face of 200 feet of interesting calcareous strata, both from an industrial and a scientific point of view, the workings having brought to light no less than five hundred distinct fossils, many of them being rare and some unique.

The fossil vulgarly known as the flying lizard (*Pterodactylus*) is found in these beds, and constitutes one of the most rare and curious, while the most famous fossil known, which is designated the Jura bird, after the locality, is found here. This, the first ancestor of birds, has teeth and a peculiar elongated tail, consisting of twenty distinct joints, with feathers on both sides, and appears to be a combination of reptile and bird (*Archaeopteryx*). No remains of mammals have been discovered in the workings.

The overburden (waste soil) which has to be removed before the stone is reached, varies in thickness from 6 to 10 feet (2 to 3 metres) at some of the quarries to 33 feet (10 metres) at others. The quarries are all worked opencast. They are by no means worked entirely for lithographic stone, most of the produce being disposed of for roofing, flooring, etc.

A few years ago, the output was at the rate of 65,000 tons per annum, of which only about 11,100 tons were suitable for lithographic purposes. At present, in the better class of the quarries, the average production of lithographic stone is only about 10 per cent. The inferior quarries yield about 40 per cent. of saleable material and 60 per cent. of rubbish, and of the 40 per cent. of merchantable material 26 per cent. are flooring-flags, 7 per cent. roofing-flags, and 7 per cent. lithographic stones.

The preceding brief details are given of the circumstances under which the most celebrated lithographic-stone quarries in the world are developed, so that they may be compared with the conditions under which it is possible to open out other quarries, extract and prepare the stone for market, and deliver it to the various European and other centres of consumption in competition with the produce of the Solenhofen quarries.

The strata in the Bavarian quarries are disposed in thin layers, varying in thickness from 0·02 inch to 6 or 7 inches, and so cut-up by joints as to cause a lamentable waste in quarrying and in the subsequent preparation of the stone for the market, besides rendering the working of the stone in essentially large superficial dimensions (which is the most valuable) exceedingly difficult.

The stones of the best quality (the bluish-grey) for lithographic purposes are practically exhausted, or their production has become so costly as to render their price from a commercial point of view almost prohibitory. The stones are so difficult to procure that the price for the grey is only quoted when specially requested, and is not included in ordinary price-lists. So scarce and valuable has this first quality (bluish-grey) stone in the Bavarian quarries become in combination with the ever-growing demand for slabs of large dimensions, and the immense

difficulties of procuring such extra sized stone of sufficient strength at any of the existing quarries, that it has now been found profitable, notwithstanding the great cost of the process, to tessellate even the smallest pieces of the best-quality stone into the requisite size of slabs in order to meet the requirements of the trade.

Prices of the Various Qualities and Sizes of Stones.

The writer finds from a price-list of the Solenhofen lithographic stone that medium-sized stones, weighing about 220 lbs. (100 kilogrammes), and measuring 24 inches by 30 inches, and $2\frac{3}{4}$ inches thick, sell at:—Bluish-grey, 52 florins, equal to $4\frac{3}{4}$d. per lb.; yellow, 21 florins, equal to 2d. per lb. The larger sizes, weighing about 720 lbs. (330 kilogrammes), measuring 60 inches by 40 inches, and about $2\frac{3}{4}$ inches thick, sell at:—Bluish-grey, 225 florins, equal to 6d. per lb.; yellow, 166 florins, equal to $4\frac{1}{2}$d. per lb. Stones of smaller dimensions and of inferior quality (the lighter shades) are much lower in price.

The following table shows the wholesale prices of three qualities of stone at the quarries in 1879, for a stone 16 by 18 inches and weighing about 1 cwt.:—

Description.	Polished for Use on One Side.			Polished for Use on Both Sides.		
	I.	II.	III.	I.	II.	III.
	s.	s.	s.	s.	s.	s.
Blue ...	15	10	5	28	19	10
Yellow ...	8	4	2	15	8	4

The stones are proportionately more expensive when of large dimensions.

London Prices of Cheap Light Cream-coloured Stone.—The light cream-coloured description of Solenhofen stone—not the famous greyish-blue—is sold at the following prices:—

Dimensions.	Thickness.	Weight per Stone.	Price per Pound.
Inches. Inches.	Inches.	Lbs.	d.
From 9 × 7 to 18 × 12	$2\frac{1}{4}$ to $2\frac{1}{2}$	13 to 50	$\frac{3}{4}$
„ 18 × 14 „ 21 × 13	$2\frac{3}{4}$	58 to 73	1
„ 21 × 15 „ 31 × 21	$3\frac{1}{4}$ to $3\frac{1}{2}$	85 to 210	$1\frac{1}{4}$
„ 30 × 22 „ 32 × 24	$3\frac{1}{2}$	207 to 264	$1\frac{1}{2}$
„ 34 × 24 „ 42 × 28	$3\frac{3}{4}$ to 4	277 to 414	$1\frac{3}{4}$
„ 42 × 30 „ 48 × 36	4 to $4\frac{1}{4}$	443 to 648	$2\frac{1}{4}$
„ 51 × 34 „ 62 × 42	$4\frac{1}{4}$	670 to 1,016	3

The Solenhofen stone is often so thinly laminated, between the main bedding-joints, as to render it difficult to procure stones of large dimen-

sions, sufficiently free from laminations, and of the requisite strength to withstand the pressure of the lithographic press. Although when first quarried, the slabs may appear quite solid, when they become dry and exposed to the atmosphere they frequently split (horizontally) along the laminæ, and become too thin to bear the necessary operative pressure. This lamination, in conjunction with the frequent minute—almost invisible—cross-joints by which the slabs are sometimes traversed, and other minor defects, often destroy the stones, and the demand is in consequence largely increased.

The principal characteristics of good lithographic stone are as follows:—It should break with a conchoidal fracture, and be of entirely homogeneous texture, free from any crystalline veins, lines, spots, or any fossiliferous markings and discolourations. The stones should be perfectly even in their induration, and have the essential property of affording the greatest uniformity in the tracings wrought upon them. If one part of the surface be more indurated than another, the encaustic delineations imparted to the stone would penetrate into and form broader lines in the parts where the stone is softest, thus rendering the work uneven.

The best quality stones are (as above mentioned) of the bluish-grey and dark-blue shades. The stones possessing these colours are of much harder and finer texture, and of greater strength than the others, probably owing to their containing more ferruginous, siliceous, and aluminous material, thus enabling artistic work of the greatest delicacy, softness, and fineness of outline to be more uniformly traced upon them.

The preparation of the stone for lithographic purposes after it leaves the quarries differs in no practical respect from the rubbing-down and polishing of marble slabs. Of course, the fineness and delicacy of the work for which the slabs are to be employed regulates the smoothness and fineness of the surface and the polish to be wrought on them. In some cases, the stones are prepared for special purposes with the care of the grinding and polishing of a mirror-plate. Stones for export are carefully packed with sheets of paper between them, so as to protect their finished faces.

The writer has not been able to obtain an analysis of the Solenhofen stone. It is said to contain 93·443 per cent. of carbonate of lime, and 1·092 per cent. of magnesia. The Croatian stone contains 96·489 per cent. of carbonate of lime, and 2·495 per cent. of magnesia.

Lithographic stone, it is needless to say, is as essential to the lithographer as type is to the printer, but the prohibitory prices of this stone, sustained by the Solenhofen quarries, have greatly restricted the

sales. Only the largest and wealthiest lithographic establishments are able to maintain a sufficiently large stock, so as to readily meet the requirements of their customers. Some large firms have a stock of many thousands' of pounds' worth of stones on hand.

If the stones could be supplied at a considerable reduction in price, the consumption would be greatly increased, as the smaller firms in the trade could then afford to maintain a larger stock.

Production of Stone from the Solenhofen Quarries.

Upon the assumption that the Bavarian quarries have now reached an annual output of 15,000 tons per annum, sold at an average price of 2d. per lb., it would have a value of £375,000 per annum. That sum is probably below the value of the total sales, as judging from official statistics, Russia alone imports £100,000 worth of lithographic stone annually.

Good lithographic stone is capable of bearing the cost of considerable land-carriage to any seaport in the world. It is a remarkable circumstance that for nearly a century no fresh discovery has been made of stone absolutely suitable for lithographic purposes. If such a discovery were made, it would—if it did not break up the Bavarian monopoly—participate in the profits of that monopoly. It is difficult to believe that there are no other localities where stone of suitable properties for the purpose of lithography can be found. The lithographic trade would, without doubt, readily welcome and support a competing stone.

The great desideratum is to discover the hard dark-coloured lithographic stone in such abundance and under sufficiently favourable circumstances, in the matter of cost of production and delivery to the centres of consumption, so as to compete in price with the cheap, inferior, light-coloured stones. The discovery would speedily drive these inferior stones off the market. The dark-coloured hard stones have numerous comparative advantages, the most important of which—especially for geographical work of all kinds—is the fact that the dark varieties of lithographic stone may be stored for a much longer period than the light-coloured, without impairing the drawings or writings wrought upon them.

Mr. Philip Reid (Newcastle-upon-Tyne) wrote that all interested in the art of lithography would be grateful to Mr. Spargo for his paper, in which he drew attention to the scarcity of lithographic stone, and to the monoply held by the owners of the Solenhofen and other Bavarian

quarries. Few persons outside the trade had any idea of the industrial importance of lithography, and how largely it was used for commercial purposes. Lithography is, of course, primarily a means of multiplying copies of drawings and writings. A plate accompanying a paper printed in the *Transactions* of The Federated Institution of Mining Engineers is made by the lithographic process, together with all maps, plans, and geographical drawings required for publication. In what is called mercantile stationery, lithography plays an important part, as the headings on writing paper, circulars, and forms are printed from stone. As a rule, they are engraved on copper in the first instance, in order that greater fineness of work may be obtained, and then transferred to and printed from the lithographic stone. Lithography is largely employed as a means of reproduction of the pictorial and other designs so largely used by advertizers and the publishers of periodicals and Christmas annuals. The demand is larger than the supply of original and attractive designs, combined with first-class colour-printing. The number of firms in the United Kingdom who undertake this class of work with satisfactory results is comparatively small, and consequently much of it is done abroad. The difficulties with which those in the lithographic business—more particularly those engaged in colour-printing—have to contend are very considerable. In the first place, there is the scarcity of good lithographic stones, and the almost prohibitive prices charged for them. Next, the climatic conditions are unfavourable, the uncertainty of the temperature and changeableness of the atmosphere in this country being great obstacles to the production of colour-printing of a high-class character, owing to their effects upon the paper, which, owing to its composition, may stretch or contract, and thus prevents an exact registration of one colour or printing upon another. The fact that lithography is based upon a chemical principle, and requires great skill and application in the artist's and printer's work deters many from entering the business. In spite, however, of the difficulties, good lithographic work is done in Great Britain, probably some of the finest in the world. Pictorial placards for use in railway stations and on hoardings are, as a rule, produced by lithographic processes. It will be readily understood that a large stock of stones must be maintained in order to carry on a lithographic business even of ordinary dimensions, the lithographic stone being, as Mr. Spargo says, what type is to the letterpress printer. Therefore, when there is such difficulty in securing stones with good surfaces, free from spots or other markings, the question naturally arises whether there is not a substitute obtainable, or a stone equalling the now famous

Solenhofen limestone to be discovered? As yet no other stone has been found so well and peculiarly adapted to the lithographic process, although search has been made in almost every part of the world. Here, then, seems an opportunity for the geologist, with a knowledge of what is required by lithographers, to make a discovery which would confer a boon upon all those engaged in the trade, and probably make a name and fortune for himself! Mr. Spargo points out that lithographers are at the present time almost entirely dependent upon the owners of the Bavarian quarries for lithographic stone. But this is not all, as the majority of the best stones are sent direct to the United States of America, where lithography is conducted upon a large scale, and enormous prices are paid for the stones. Europeans therefore have a two-fold difficulty to contend with—the monopoly enjoyed by the proprietors of the Solenhofen and Papenheim quarries, and the fact that the majority of the best stones are exported to America. English lithographic firms as a rule buy the stones from London dealers or agents for the German quarry owners. So far, he (Mr. Reid) had only spoken of lithographic stone as the substance upon which drawings and writings were made, and from which copies were printed by means of the lithographic press or machine. However, a substitute for stone is used to a certain extent by lithographers, and this is zinc-plate (specially prepared for the purpose), which possesses certain advantages: it is more portable, and when used for the retention of work is more convenient for storing purposes. The first cost, too, is much less. For instance, a zinc-plate, measuring 32 inches by 42 inches and $\frac{1}{8}$ inch thick, costs about £1, while a lithographic stone of the same size, and 4 inches thick, costs about £3 15s. The use of zinc-plates is not, however, so satisfactory, and they do not last so long as stone. There is also a certain amount of prejudice on the part of the lithographic printer against their use. The ink of the drawing does not penetrate the surface of the zinc in the same way as that of the stone; the adhesion is consequently not so strong, and there is greater risk in printing; the zinc-plate does not absorb water so freely as stone, and care has also to be exercised to prevent corrosion of the plate. Zinc-plates are in daily use in most lithographic establishments for the cheaper classes of lithographic work. It has recently been announced that aluminium is likely to become an important substitute for lithographic stone, and that trials made with it have proved highly satisfactory. In conclusion, he would describe the processes upon which lithography was founded, referred to by Mr. Spargo at the beginning of his paper. Lithography was founded upon three chemical principles, viz., (1) the antagonistic

qualities of grease and water, (2) the affinity of one greasy substance for another. and (3) the power with which a certain substance (forming the printing surface) attracted to itself both grease and water. The art of lithography really depends upon the first-named principle. For instance, the finest lithographic stone, or any other material of a like compact substance offering the same advantages may be used, a drawing made upon it in greasy ink, the roller charged with lithographic printing ink may be applied, and an endeavour made to take an impression on paper by means of the lithographic press. It will, however, be impossible to obtain an impression without the application of water to the surface of the stone previous to using the roller, as will be seen from the following account of the actual process of lithographic printing. The process of printing is simply as follows:—A drawing or writing being made upon the lithographic stone with ink prepared for the purpose (the ingredients of which are given below), the stone is taken in hand by the lithographic printer and put through a number of processes. He first "gums the stone up," to use a technical expression, or, in other words, covers the surface with gum and water. The gum prevents the ink of the drawing and that used in printing from spreading. After washing the gum off with clean water, enough having entered the pores of the stone for the above purpose, he passes a damp cloth over the surface, so as to equalise the moisture, and then proceeds "to roll up the work" with a roller charged with lithographic printing ink, which, of course, adheres only to the greasy lines of the drawing or writing. After this he "etches" the stone, that is to say, applies a sponge filled with dilute nitric acid, which removes the superfluous grease of the ink and renders the surface of the stone more absorbent of water. After again repeating the processes of gumming, washing off the water, applying the damping-cloth, and rolling up the work, he places the stone upon the bed of the lithographic press, and proceeds to take an impression on paper (the press being worked on the lever principle). The damping and rolling is repeated for every impression made. A lithographic hand-press is used chiefly for the preparation of proof copies; but where a number of copies are required, the impressions are printed by machines driven by steam or other power. The ink ordinarily employed in drawing or writing on lithographic stone is composed of tallow, soap, wax, shellac, and lamp-black. Mr. Spargo mentions certain others, but they are not necessary ingredients, and are not ordinarily employed.

DISCUSSION UPON MR. J. R. WILSON'S PAPER ON "THE SHAW GAS-TESTER."*

Mr. JOSEPH R. WILSON (Philadelphia), after reading the criticisms on his paper, replied that he very much regretted that he could not be present at the Newcastle meeting with the Shaw gas-tester to demonstrate its accuracy by practical experiments, as without any actual knowledge of the instrument, the gentlemen who have criticized its ability and applicability have expressed themselves from a theoretical standpoint only, and he was not stating anything new when he now said that "a grain of experience is worth an ounce of theory." He desired to lay particular emphasis upon this point, as the introduction of the steam-engine to supersede horse-power was at the time most violently opposed by many of the leading engineers. He was not at all surprised to find that the scope of the Shaw gas-tester was beyond the understanding of those unaccustomed to its use, for the harnessing of gas to machinery for practical analysis must surely meet with incredulity from those who have all their ideas associated with the old methods. The remarks of Prof. P. P. Bedson (Newcastle-upon-Tyne) are those of a scientist desirous of advancing the cause of science, and not wedded to any tradition, but open to conviction even though the matter at issue happens to be entirely new. He now regretted that he had not sent an instrument to Prof. Bedson a month before the meeting, for that gentleman at least could have demonstrated its operation and accuracy. Mr. James Ashworth (Derby) stated "that the Shaw apparatus appeared to him to be cumbersome, unwieldy, and totally unsuitable for the requirements of coal-mines." This sweeping criticism is another evidence of what every new and valuable invention has to encounter. It is particularly unacceptable, coming from one who has never used the new method of analysis, and who is utterly unfamiliar with the construction of the apparatus or the principles upon which the analyses are made by its means. Mr. Ashworth stated that the Shaw gas-tester had one point in common with the different safety-lamps, viz.: "that the test for gas was made with 'fire,' and thus compared, it stood at a great practical disadvantage." He (Mr. Wilson) would reply that the Shaw gas-tester stood at a great practical advantage

* *Trans. Fed. Inst.*, vol. viii., page 161.

in this respect, since a man could enter any section of the mine without a light and capture a sample of the air by means of rubber bags and a diaphragm hand-pump, whether it be from the face, the goaf, or a hole in the roof, an operation which could be performed in perfect safety. The bags are then carried outside the mine and attached to the instrument, which will reveal in a few seconds the true nature of the condition of the ventilation of the mine in each section whence the air was taken. The necessity for the presence of the safety-lamp with its flame is the great disadvantage of the lamp for testing dangerous places. He might also cite another instance here where the Shaw method of testing gas was particularly valuable, on account of the safety of those who have to make the test. The condition referred to is the ability to capture the air through an aperture in a closed door, and thus determine the character of the ventilating current of air on the other side. This method of application is also most useful in the case of mines which are sealed up owing to fire. The character of the air in any accessible place can be ascertained by inserting a brass tube through a suitable aperture, and pumping the air by means of a diaphragm hand-pump direct from the mine into the rubber bags, which can then be attached to the Shaw gas-tester and their contents ascertained with certainty and in absolute safety. Without having ever used or even seen the Shaw gas-tester, Mr. Ashworth boldly states that, "its deductions were liable to most serious inaccuracies in practical use," and goes on to state that "he did not dispute the possibility of its finding the correct percentage of fire-damp, or carbon monoxide, or carbon dioxide, or sulphuretted hydrogen, if each be present by itself and mixed with air, but if there were such an ordinary mixture of fire-damp, carbonic oxide and carbonic acid gases with air, together with others from gob-fire, it appeared to him that the apparatus could not possibly give a correct result." It took a Newton to discover the law of gravity, and what appears to Mr. Ashworth to be impossible was easy of solution to the inventor of the Shaw gas-tester. Before proceeding farther, he desired to recall the fact that Mr. Ashworth sought extraordinary conditions on which to oppose the instrument under discussion and not the everyday conditions as they actually exist in the mine. It is not to be supposed that every mine is on fire, or that the atmosphere of these mines is always made up of such deadly gases as those enumerated by Mr. Ashworth. The gas that the Shaw gas-tester was designed to detect is pure fire-damp alone, although its uses have been extended to the detection of the presence and percentage of other gases by the inventor. However, in order to meet the objections raised by Mr. Ashworth he

might briefly state that by a simple and rapid process, gas captured from a mine on fire may be passed through suitable absorbents, and an accurate analysis obtained in every instance. He was still of opinion that the Davy safety-lamp was the most sensitive oil-lamp for testing for fire-damp, but he did not claim that it was the safest. In reply to Mr. J. L. Hedley's desire to know what is done when certain percentages of gas are found, his reply was that with a positive knowledge of the condition of affairs we are in a better position to regulate them, and if one air-split is carrying 0·1 per cent. of fire-damp, another 1 per cent., and another 3 per cent., proper means are provided for distributing the regular air-supply in proportion to requirements; in other words, the air-supply is under good control, so that it can be increased or decreased in any split as circumstances may demand. A normal state of affairs is not to be expected. The use of the instrument is but an adjunct to present appliances, and it was not designed to do away with any existing devices of value, but to go hand in hand with them. The Shaw gas-tester is intended for protection in the aggregate rather than in the abstract, and it stands entirely by itself for this purpose, its principal use being for the attainment of a better knowledge of exactly what each and every air-split is carrying, the condition of old workings (where it would be dangerous to test with a safety-lamp), the contents of cavities in the roof produced by falls, etc. The instrument is not intended to be taken into any working-place. The gas is captured in rubber bags by means of a diaphragm hand-pump,* and brought to the instrument, which may be located in the lamp-room at the foot of the slope or shaft, if it be the downcast, or at the mouth of the shaft or slope. Mr. Hedley's idea that the introduction of additional safety-appliances would rather add to than reduce the danger, etc., was an incongruity without precedent in his (Mr. Wilson's) experience, and was too paradoxical for further discussion. The Shaw gas-tester was never intended to take the place of any existing means for the detection of gas or protection of life and property, but as a positive means of ascertaining the value of all such appliances, and as a means of knowing accurately the general condition of the ventilation in every part of the mine without any guesswork and without any limit, which latter feature is a feature not incorporated in any other known appliance for detection of gas except the Shaw gas-tester. The Davy, Clanny, Thomas, and every other safety oil-lamp will not show gas unless 2½ per cent. is present, and will fill with flame at about 8 per cent. This

* *Trans. Fed. Inst.*, vol. viii., page 164.

is the limit of their use. The alcohol and hydrogen-lamps commence to show the presence of fire-damp at about ½ per cent., and become filled with flame much earlier than oil-lamps; but it must be distinctly remembered that the Shaw gas-tester will show any percentage of fire-damp present from 0·001 to pure gas. He wished to eliminate the impression that the Shaw gas-tester is designed to do away with lamp tests, as the safety-lamp will always be indispensable for tests at the working-face, where crude but frequent tests are necessary. Mr. A. L. Steavenson (Durham) stated that "the fact that an instrument cost £100 should not stop the use of the machine if it were really useful. Many colliery owners had spent thousands of pounds on new ventilating-fans, and the cost should not prevent the adoption of any measure of safety." He also "suggested that each of H.M. Inspectors of Mines should be provided with a Shaw gas-tester, and that they should visit each mine periodically, and take samples of the air in the main return airways." But after listening to the remarks of two other gentlemen, his enthusiasm for the introduction of this safety-appliance seems to wane, as he thinks that "there did not appear to be any certainty that the results recorded by the Shaw gas-tester were really accurate. They were obtained by a mechanical apparatus." The fact is that the very mechanism that he decries absolutely reduces the personal equation of error to *nil*, simply because it is mechanical. The proof that the instrument is accurate is amply provided for in the construction of the apparatus itself, in its ability to pump any mixture of gases desired into a rubber bag, and then show what the bag contains. In other words, a known quantity of gas may be placed into a bag, and be treated as an unknown quantity. The instrument will then repeat the same test over and over again, always showing the same result, which places its accuracy beyond dispute. Mr. H. G. Graves' reference to Mr. H. Le Chatelier is somewhat amusing, for after stating that Mr. Le Chatelier condemned the use of the Shaw gas-tester, he goes on to state that Mr. Le Chatelier had designed a small test-tube arrangement to be used in its place. Prof. H. S. Munroe recently stated that:—

Mr. Chesneau, in his paper, gives full credit to Mr. Thomas Shaw, of Philadelphia, for his method of determining the percentage of fire-damp or other explosive gas when mixed with air. Mr. Shaw was the first to demonstrate that a definite minimum percentage of gas must be present to make the mixture explosive, and that the line between an explosive mixture and one that is non-explosive is sharp enough for quantitative tests. Mr. Shaw finds, for example, that 6 per cent. of pure marsh-gas in air gives an explosion; and one-tenth of 1 per cent. less is non-explosive. Mr. Le Chatelier's experiments, as cited by Mr. Chesneau, fully confirm Mr. Shaw's results, and show that his method of determining fire-damp is

accurate and reliable. Mr. Chesneau, however, remarks that the Shaw apparatus is "much too complicated, and, therefore, too costly for general use in mines. Moreover, it does not lend itself easily to the analysis of samples taken underground." A Shaw gas-tester has recently been purchased for the use of the School of Mines, and my experience with the apparatus thus far has shown that Mr. Chesneau's criticism is not well-founded. The apparatus, costing upwards of £100, is not cheap; but it is by no means "too costly for general use in mines," when its many advantages are considered. It is not as complicated as would at first sight appear, and it is admirably adapted to the analysis of samples taken underground, making the test in much less time and demanding much less skill on the part of the operator than the simpler apparatus of Mr. Le Chatelier. In the hands of a skilled chemist the graduated tube of Mr. Le Chatelier will doubtless give as good results as in the hands of its distinguished inventor; but in the less skilful hands of our mine-officials, who find no difficulty in using the Shaw gas-tester, I fancy the Le Chatelier tube would prove impracticable.*

Mr. M. Walton Brown makes a very good suggestion for the capturing of samples of air, but he (Mr. Wilson) had found that for use in coal-mines, the diaphragm hand-pump and rubber bags (which can be filled in a few seconds) are superior to any other method. Prof. F. Clowes stated that "there existed at present cheap and easily portable forms of apparatus, some at least of which were equal in accuracy and delicacy to the Shaw tester." In reply to this statement, the writer challenges Prof. Clowes to the proof, and the gas he selects for the trial is fire-damp. He hoped to be able to visit England in the spring or the early part of next summer, and would bring a Shaw gas-tester with him. Some interesting points would no doubt be settled at that time. In the meanwhile, he suggested that the Government should send over one or two of the Inspectors of Mines to investigate this matter at an early date in the interest of those whose lives are dependent upon their wisdom and sagacity, for protection from explosive gases in coal-mines.

Mr. W. C. BLACKETT (Durham) wrote that as an ingenious display of mechanical skill the Shaw gas-tester was most admirable, but as a practical device it was not so useful. In the discussion which had formerly taken place most of its drawbacks had been pointed out by a number of experts. What, however, struck him as somewhat noteworthy was the assumption† that the conditions of working of persons at the face or elsewhere in a mine would be at all altered by the possession at the mine of a Shaw gas-tester. Was it to be assumed that in a mine having a ventilating-current of 100,000 cubic feet per minute it would be possible for 2 per cent. of gas to exist and its presence never even be suspected, even though only ordinary safety-lamps were used? Would

* *Trans. American Inst. Mining Engineers*, vol. xxii., page 726.

† *Trans. Fed. Inst.*, vol. vii., page 165.

this quantity of gas have come off so regularly and imperceptibly as never to have shown itself in bulk at some point? He ventured to think that such a state of affairs could not exist. Farther, in this country it would not be the case, in the event of some accident to the ventilation that "the man at the face," feeling "the air grow hot and sultry," and realizing "that the ventilation had been stopped," would "come down with his light" (he would not in this country in such a mine have a naked light) and ascertain the reason, and in so doing walk into the explosive mixture, and hurl himself and a score of comrades to death. At any rate, if there were such a speculative person at the face, the possession of a Shaw gas-tester in the manager's office on the surface would hardly be likely to influence his inquisitive movements. Even though such an extraordinary state of affairs could exist as that of a mine having 2 per cent of fire-damp in its main airways and that its presence had only been revealed to the management by a Shaw gas-tester, the men at the face, in the event of suspected danger, could by special instruction do no more than would workmen in this country under the special rules, viz., retire carefully therefrom to a place of safety, which certainly would not be the return airway. The calculation* as to how long an air-return passing 100,000 cubic feet per minute would require to be fouled with 10 per cent. of gas when 2 per cent. was ordinarily present was quite erroneous. Manifestly, if the ventilating-current was suspended, it was no longer a question of percentage of fire-damp in the air-current, but was one of how long 2,000 cubic feet of gas per minute would be in fouling the whole cubic contents of space in the mine. He therefore ventured to say that instead of being ten minutes in forming a 10 per cent. explosive compound in most mines it would be a very great deal longer.

The President moved that a cordial vote of thanks be accorded to the owners of collieries and works, to be visited during the course of the meeting, and to the authorities of the Mason Science College for the use of their rooms.

Mr. W. C. Blackett seconded the motion, which was agreed to.

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* *Ibid*, page 165.

Mr. G. A. MITCHELL (Glasgow) proposed a vote of thanks to the South Staffordshire and East Worcestershire Institute of Mining Engineers for the arrangements which they had made for the reception and entertainment of the members.

Mr. STOKES seconded the resolution, which was unanimously agreed to.

Mr. H. C. PEAKE moved, and Mr. J. BARROWMAN seconded, that the thanks of the members be accorded to the President for his services in the chair.

The PRESIDENT acknowledged the compliment, and the meeting was then closed.

The following collieries and works were, by kind permission of the owners, open for inspection during the course of the meeting on February 12th and 13th, 1895:—Hamstead colliery, Sandwell Park colliery, Messrs. Tangye's engineering works, the Mint, the Birmingham Railway-carriage and Wagon Company's Works, and the Midland Railway-carriage and Wagon Company's works.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,

JANUARY 14TH, 1895.

MR. E. B. WAIN, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

FLOODING OF THE DIGLAKE COLLIERY.

The PRESIDENT referred to the flooding of the Diglake colliery, Audley, and moved a vote of sympathy with the bereaved families, and also with Messrs. Rigby, the owners of the colliery.

Mr. J. C. CADMAN seconded the motion, which was agreed to.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. C. E. DE RANCE, Assoc. Inst. C.E., F.G.S., F.R.G.S., F.R. Met. Soc., Geological Survey of England and Wales, 28, Jermyn Street, London, S.W., and 55, Stoke Road, Shelton.

Mr. JOHN C. T. RASPASS, Colliery Manager, Elm Grove, Madeley, Salop.

DISCUSSION UPON MR. WOODWORTH'S "NOTES ON THE PRACTICABILITY OF WORKING THE THIN COALS OF NORTH STAFFORDSHIRE BY THE ADOPTION OF MECHANICAL APPLIANCES."*

Mr. WOODWORTH, replying to a question, said that he had not much to add to his paper. One matter was as to the gradient; the line drawn in the first instance might be 12 inches per yard; then half-end and half-face would be under 9 inches per yard. Holing at 12 feet per man per day could easily be beaten by machine, and he should say where 5 yards per shift 3½ feet under was made, that could be beaten comfortably unless the conditions were unfavourable to the machine. Mr. Sutcliffe had said that the labour-cost was 2d. per square yard, and he would provide the machine and undertake to do the work for 5d. per square yard. It had been reported that recently, at the Springbank colliery, Airdrie, a trial took place of a Rigg-and-Meiklejohn coal-cutting machine. It was one of the usual size, with cylinders 7¾ inches in diameter, and was worked by compressed air at a pressure of 40 lb. per square inch. The machine was 7 feet 10 inches long, 2 feet 10 inches wide exclusive of the cutter, and 1 foot 10 inches high on the rails. The grip cut by this machine was only 2¾ inches to 3 inches. It was worked by four men, one to attend to the machine, two laying rails and setting props, and another following the machine, clearing out the cut to let the coal drop. The cut was made 3 feet under in a seam of coal 2 feet 8 inches thick, and the wall to be cut was 210 feet long. This whole length was cut in one hour and thirty minutes, and at this rate a cut of considerably over 1,000 feet could be made per shift of eight hours. These remarks were based on systematic laying out of the work for a considerable area, not as probable results of small trials, as the plant and incidental expenses were too heavy when spread over a small area. The increased proportion of extra round coal in many cases would ensure a good profit, even if the cost of working were as heavy as when done by hand labour.

Mr. GILLOTT, in reply to questions, stated that coal-cutting machines had been worked at an inclination of 1 in 4, the machines cutting up and down the face. In the case of steeper gradients, the machine was worked at an angle to the dip, so as to lessen the inclination. A machine

* *Trans. Fed. Inst.*, vol. viii., page 215.

working under ordinary circumstances in fire-clay could hole about 250 to 300 feet per shift: this result was obtained when holing in material of which only 4 square yards could be holed per man per shift. Two men were required to attend to one machine—one to lay the rails and the other to sprag the coal, etc. The machine could travel in a width of 3½ feet at the face; it was better if there were 4 feet, so as to give the men a little more room to work in. The coal that was holed in the night could be removed during the following day, and there was no interruption of the work, because the machine started back again and cut to the other end of the face.

Mr. HASSAM enquired if it were not something new for a coal-cutting machine to work in either direction along the face? Some years ago, he had experience with the Gillott machine in South Yorkshire, and at that time they would only cut in one direction, and considerable difficulty was met with in getting them back along the face for another cut. In fact, in some instances it was impossible to get the machine along the face, and it had to be conveyed from one end of the face to the other by means of the gate-roads. A machine which would cut in either direction was a great improvement upon the old ones.

Mr. GILLOTT remarked that machines on that principle were introduced five or six years ago. The object was to obviate the necessity of shifting the machine, as sometimes it had to be carried a great distance along a bad road. The weight of the machine was about 18 cwts. The largest diameter of cutting-wheel in use did not exceed 4 feet. He preferred to cut to a depth of about 3½ feet. The average cost in a 3 feet coal-seam was about 4d. per ton, including labour and all other expenses. It took about 15 horse-power to drive a machine.

Mr. PREST said that he had no doubt as to the economy under favourable conditions and where air-compressing machinery was available.

Mr. GILLOTT said that six machines would be required to hole 500 tons of coal in ordinary fire-clay in a 3 feet seam, on the assumption that each machine cut a little over 240 feet per shift.

Mr. PETER HAMPSON wrote that the ordinary mode of working the thin seams (18 inches) in the Bolton district was as follows:—When the outside of the shaft-pillar was reached, everything was opened out in wide-work, and drawing-roads were put in every 42 feet. Cross-roads were made as the face advanced, at distances varying from 450 to 600 feet apart. He attributed the successful working of thin seams to two causes, viz., dirt-holing and working the coal in the right direction. If they attempted to get the coal on the face, they found that the dirt was very

hard to hole, that they did not get the same weight of round coal, and that the roof was bad and difficult to maintain. Consequently the workings were always put on the end, or half-end and half-face, the end being rather the best. They had a warrant (under the coal) in which the holing was made about 3 or 4 inches thick, and it was surprising to see the depth which could be holed with very little balching. There were generally two colliers and a drawer in each working-place, and they took 30 feet on the higher side and 12 feet on the lower side. This difference was made on account of the coals having to be shovelled into the drawing-road as they could not take the tub along the face. The colliers knelt or stooped behind each other, and turned the coal over gently, and it was passed on in this manner till it reached the drawing-road, so that very little coal was broken ; in fact, they were putting 75 to 80 per cent. of round coal into wagons. Each set of men made their own roads, either blasting the top or bottom-stone for a thickness of 2½ to 3 feet and 5 feet wide. The *débris* from the cut and the holing-dirt packed the goaf solid, so that with the exception of a few props, no timber was required at the working-face, and very little in the roads. The main haulage-roads were made by day-wage men. The goaf being packed solid, the roads stood so well that very few day-wage men were required although the output was the somewhat large one of 2,000 tubs daily. The haulage-roads were made 10 feet by 6 feet. The haulage was exclusively on the endless-rope system, the engine being placed on the surface, and he thought that if they introduced a few Lancashire colliers from some low seam, they would not require any mechanical means of getting coal, as the local men would soon take example from them.

Mr. Makepeace said that in the North Staffordshire district, there were no coal-cutting machines at work, and the majority of the members knew little about them.

The meeting was then closed.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,

JANUARY 19TH, 1895.

MR. THOMAS DOUGLAS, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council of that day.

The following gentlemen were elected, having been previously nominated:—

HONORARY MEMBER—

Rev. HENRY PALIN GURNEY, Principal of the Durham College of Science, Newcastle-upon-Tyne.

MEMBERS—

Mr. BASIL JOHN ATTERBURY, Mining Engineer, 18, Eldon Street, London, E.C.

Mr. WILLIAM BIBBY, Manager of the Raub Australian Gold Mining Co., Limited, Raub, Pahang, Malay Peninsula.

Mr. HARRIS BIGG-WITHER, General Manager of the Roburite Explosives Co., Limited, 10, Swinley Road, Wigan, Lancashire.

Mr. GEORGE BOOLE, Mining Engineer and Colliery Manager, Rainford, near St. Helens, Lancashire.

Mr. HENRY HUNTER CAMPBELL, Land and Mine Surveyor, and Mining Engineer, Sutton Hall, St. Helens, Lancashire.

Mr. JOHN FLINT, Colliery Manager, Broomhill Colliery, Acklington, Northumberland.

Mr. WILLIAM KENNEDY, Geologist and Mining Engineer, Austin, Texas, United States of America.

Mr. LLOYD WILSON, Colliery Managing Director and Engineer, Flimby Colliery, Maryport.

Associate Members—

Mr. John S. Bolton, Electrical Engineer, 78, Brighton Grove, Newcastle-upon-Tyne.

Sir George William Elliot, Bart., M.P., 16, Great George Street, Westminster, London, S.W.

Mr. George B. Saunders, Chemical Agent, etc., c/o Messrs. Dawson, Saunders, & Todd, Maritime Buildings, Newcastle-upon-Tyne.

Students—

Mr. Henry Dunford Cowan, Mining Student, Elswick Collieries, Newcastle-upon-Tyne.

Mr. James Bertram Sample, Mining Student, South Tanfield Colliery, Stanley, R.S.O., County Durham.

The following gentlemen were nominated for election :—

Members—

Mr. Alexander Agassiz, Mining Engineer, Museum of Comparative Zoology, Cambridge, Massachussetts, United States of America.

Mr. Thomas Bates, Colliery Manager, The Grange, Prudhoe-upon-Tyne.

Mr. Robert Gilman Brown, Mining Engineer, Box 946, Butte, Montana, United States of America.

Mr. William Clifford, Mining Engineer, Pittsburgh, Pennsylvania, United States of America.

Mr. John S. Crawford. Consulting Engineer, Kingston, Sierra County, New Mexico, United States of America.

Mr. John Henry Darby, Steel Manufacturer and Engineer, Pen-y-Garth, Brymbo, Denbighshire.

Mr. David Evan Davies, Colliery Manager, Cwmaman Colliery, Aberdare.

Mr. Thomas Ingleby Dyson, Metallurgist, Mount Morgan, Queensland.

Mr. Edward Edwards, Colliery Manager, Maindy Pit, Ocean Coal Company, Ton Pentre, South Wales.

Mr. G. Graves Gifford. Mining Engineer, Perth, Western Australia.

Mr. George Ernest Gregson, Land Agent, Land and Mine Surveyor, 11, Chapel Street, Preston.

Mr. Joseph Hadfield, Colliery Manager, Hulton Collieries, Chequerbent, Bolton, Lancashire.

Mr. David Hannah, Mining Engineer, Brynderwen, Ferndale, South Wales.

Mr. C. D. Sullivan, Mining Engineer, Bonang, Delegate, New South Wales.

Mr. Jesse Wallwork, Assistant Mining Engineer, Haydock Collieries, near St. Helens, Lancashire.

Associate Member—

Mr. George Beneké, Managing Director of an Explosives Manufacturing Company, 70, Gracechurch Street, London, E.C.

Associate—

Mr. John Rivers, Master Shifter, Front Street, Tudhoe Colliery, County Durham.

Student—

Mr. Henry Scott Stratton, Mining Student, Cramlington Collieries, Northumberland.

DISCUSSION UPON THE "REPORT OF THE PROCEEDINGS OF THE EXPLOSIVES COMMITTEE." *

Mr. W. C. BLACKETT, as a suggestion, enquired whether the Explosives Committee, being satisfied that there was as yet no "flameless explosive" would not be justified in changing the name from that of "Flameless Explosives Committee" to some other name which would be more truly descriptive. The *Report* † stated that owing to the contradictory results of many previous experiments, it was desirable to clear away doubts and uncertainties in the employment of safety-explosives, and even if this object had not been entirely effected, the experiments of the committee have advanced the general knowledge of the subject. The first doubt, however, which occurred to him (Mr. Blackett) was as to the practical value of the experiments, owing to the fact that the conditions usually obtaining in a mine have not been obtained in the apparatus used: for example, the use of the varnished brown-paper diaphragm. He was not going to say that similar conditions were never approximately produced in a mine, but they ought not to be; and any one firing a shot under such conditions would be acting as wrongly as though he permitted the use of an imperfect safety-lamp. Under ordinary conditions, such a state of circumstances did not exist; and they were at once met with the question, as to whether and how this diaphragm affected the inflammation of the contained gases. He (Mr. Blackett) was of opinion that confinement might increase the explosive violence of the gases; that the firing of a shot might produce a state of compression of the gases before the diaphragm was fractured; and that this state of compression might produce a readier ignition, and would lower the temperature at which the ignition could take place. Would the gaseous mixtures therefore have been as readily ignited had their movement been less restricted? The means for reasoning in some parts of the *Report* was somewhat insecure; for instance, in the pit-gas experiments, no ignitions were recorded in twenty-five shots of bellite, while with securite, one ignition took place in the only shot fired.‡ Apart from the perhaps far-fetched casual doubt that, had one more shot of bellite been fired an ignition might have been got, and had

* *Trans. Fed. Inst.*, vol. viii., page 227. † *Report*, page 5. ‡ *Ibid.*, page 19.

twenty-five more shots been fired of securite there might have been no more ignitions; the conclusion is, that bellite is safer than securite. Now, apply the same line of reasoning to the experiments with carbonite:* out of eight experiments in 10 per cent. of coal-gas and with 1 inch of stemming only one ignition was obtained; but in one experiment in 10 per cent. of coal-gas with 6¾ inches of stemming there was one ignition. According to the reasoning used in the first instance, they ought to conclude, in the case of carbonite, that 1 inch of stemming was safer than 6¾ inches. It may be observed, that if the members had had no practical experience of the working of explosives in collieries, and did not know that "when blasting in coal or stone, the length of stemming is of greater importance"† they would have concluded from the experiments "that no substantial degree of safety is attained by the extra length of stemming used"‡ This statement is a farther illustration of the danger of trusting to experiments, which do not closely follow the actual conditions of a mine. The stemming used was "damp puddled clay"§ and unless the consistency were the same in all the experiments, the comparisons are worthless. A small excess of water, in a long length of stemming, would make it offer less resistance than a shorter length of the same clay well rammed and in a dryer state. He (Mr. Blackett) decidedly differed from the committee and ventured to affirm that a substantial degree of safety was obtained by extra length of stemming. It was admitted by the committee that the weights of the shots used do "not represent the relative strengths of the several explosives when fired confined."‖ From this statement it may be inferred that except in the case of unstemmed shots,¶ it is useless to endeavour to compare any of the explosives. Nevertheless, the committee proceed to make such comparison, saying "under conditions of stemming, however, for the sake of uniformity, comparative experiments were also made with the weights of the several explosives" as given in the table of strengths.** Referring, however, to the indisputed permission given for comparison of the various explosives when fired unstemmed, he greatly doubted whether there was any mode of ascertaining the relative strengths of explosives, so as to obtain the comparative actual effects in practical use in mines; in other words, it was very questionable whether the figures recorded by the committee as representing the relative strengths of the explosives did represent their actual mining strengths. It seemed to

* *Report*, page 34. † *Ibid.*, page 32. ‡ *Ibid.*, page 31. § *Ibid.*, page 31.
‖ *Ibid.*, page 18. ¶ *Ibid.*, page 17. ** *Ibid.*, page 18.

him that the Trauzl method ignored a very important factor, and that was the time or duration of the explosion. The rapidity of the impact of the high explosive is such that, in the case, say of coal, it vents much of its force in crushing to powder those parts which immediately surround it, and much more explosive is required to do the necessary work than would be the case were the force distributed over a longer period of time. Gunpowder has a great advantage in this respect, since its work is spread over a longer time, and its time of contact is greater. There is the same kind of difference in the use of a wooden mallet and a steel hammer. The Trauzl method does not take this difference of action of explosives into account, and Table I.* would lead one to suppose that it would be necessary to use 25 ounces of powder in order to get the equivalent strength of 1 ounce of bellite; consequently the table is quite valueless from a practical point of view. The *Report* says that the explosives considered are probably not used for the purpose of getting coal. It is a fact, however, that a few collieries do use such explosives for getting coal, and it was recently ascertained that sixteen collieries in the county of Durham were using high explosives for coal-getting. The next doubt which he (Mr. Blackett) had was as to flame. Flame is a somewhat indefinite term applied to a phenomenon of heat and light. One human sense discovers the first and another the latter, but no one sense can receive both impacts; consequently it is questionable whether the human eye is a sufficiently reliable organ for the purpose of testing phenomena, the temperatures of which are the most important features, yet the eye is what the members of the committee have used in their observations. They have not attempted to observe the actual temperatures, but have relied solely upon the effect of flashes of light upon the eyes of various persons. The difficulty of recognizing by this means what was actual flame and what was light is mentioned in the *Report*,† together with the somewhat curious conclusion that such observations could only be reliable if made in daylight. The reason for this opinion may possibly be found in the fatigue of the retina of the eye (induced by the more powerful daylight) whereby it becomes to some extent insensible to weaker light, and exemplifies one of the defects of the eye as an optical instrument. Not only were the committee satisfied with the eye for this purpose, but it is apparently assumed that all eyes could observe alike. This reasoning is obviously unsound, as one eye will see rays of light to which another is absolutely blind. No tests for eyesight are mentioned in the *Report*, and the difference of observers' powers in this respect

* *Report*, page 17. † *Ibid.*, page 22.

probably accounts for such an instance as, say, that which is noted in experiment No. 8, of June 30th, 1893, where flame is observed in the first five sight-holes, not observed at No. 6, but seen again at No. 8. Was there flame at No. 6 sight-hole? If not, then how could it be seen at No. 8? The suspicion, one naturally arrives at, is that either a flash of light was there, and could not be seen at No. 6, or it was not there, and the observer at No. 8 sight-hole imagined that he saw it. On what grounds, too, did the committee differentiate their observations so as to call what was seen in the case of explosives "flame," and in the case of detonators "flash?" The question that occurred to one, on looking through Table VI. of experiments with detonators * showing that the detonator alone may cause the ignition of gas, was, how are we to know whether it was the explosive used or its detonator which caused certain of the ignitions that took place with unstemmed shots?† The *Report* quoted the experiments of the French Commission to the effect that "detonators containing from 23 to 31 grains of fulminate of mercury did not ignite mixtures of fire-damp," ‡ and goes on to say that the committee's experiments are not in accord therewith, inasmuch as "mixtures of both coal-gas and air and fire-damp and air have been ignited by detonators containing 15·4 grains of fulminate of mercury." § A reference to the Report of the French Commission proved that a deficient quotation had been made. The French Commission state that plugged detonators with 23 and even 31 grains of fulminate did not ignite fire-damp, and that unplugged detonators with 23 grains of fulminate had ignited gaseous mixtures.‖ The committee make no distinction between plugged and unplugged detonators, and from their description in the *Report* it was to be inferred that unplugged detonators were used.¶ The conclusion that fire-damp was more easily ignited by detonators than coal-gas, would have been more convincing had an equal number of shots been fired in each gas.** It is gratifying to find that the committee's conclusions—Nos. 1, 4, and 5††—are practically in accord with those of the French Commission.‡‡ It is probably indisputable that some of the safety-explosives have as much right to the prefix "safety" as safety-lamps, and the experiments of the committee appear to prove that when properly stemmed

* *Report*, page 27. † *Ibid.*, page 23. ‡ *Ibid.*, page 26. § *Ibid.*, page 27.

‖ *Report of the French Commission on the Use of Explosives, etc.* Translation by Messrs. W. J. Bird and M. Walton Brown, 1891, pages 40 and 41.

¶ *Report*, page 28. ***Ibid.*, page 29. †† *Ibid.*, pages 40 and 41.

‡‡ *Report of the French Commission, etc.*, translation, page 43.

they are incapable of igniting fire-damp. Nothing more could be said of a safety-lamp, if properly handled it could not ignite fire-damp. If, therefore, in the hands of one workman the two articles are equally safe, the position of the safety-explosive is the better as regards gas, since, where only picked workmen are allowed to handle an explosive, all workpeople are allowed to carry safety-lamps. The second conclusion must be true, that perfect mixing of the ingredients of an explosive is important. He, however, would like to know upon what evidence the committee based the conclusion that the variable results of the experiments with the explosives were due to their defective admixture. This appears to be more of a conjecture than a conclusion, and manifestly, if it could be alleged against any explosive, it might equally apply to detonators, gas mixtures, etc. The third conclusion, as to careful storage, is well known, although it may not be carried out by all users of safety-explosives. The sixth and seventh conclusions have, to some extent, been qualified by the speaker's remarks as to flame. It did not appear to him that the smooth bore of a cannon and a plug of wet clay were fair representatives of a stone borehole and its stemming; and he was disposed to question whether such mobile substances as wet clay or water were as safe as the usual slightly damp borings of stone, which tend to set in the borehole and into its rough sides; and farther, he thought that, were the stemming increased so as to sufficiently increase the work to be done in dislodging it, even in the case of a cannon, it would be found that the emission of heat would be insufficient to fire an explosive mixture of coal-gas and air. He (Mr. Blackett) had made some experiments with stemming in an iron pipe (1 inch in diameter), and had measured the force required to dislodge well-rammed stemming. He obtained the results tabulated below:—

Description.	Stemming. Length in Inches.	Force required in lbs.
Damp puddled clay	6 ...	56
„	12 ...	80
Damp seggar boring	2 ...	56
„ „	4 ...	336
„ „	6 ...	1,232

Had the committee, therefore, used seggar-borings instead of clay, it was only reasonably to suppose that the results would have been more satisfactory. The committee's experiments warn miners against the danger of blown-out shots, and therefore against using a greater weight of explosive than is necessary to do the work required; and, as manifestly, a workman who had already charged a hole would have used fully as much explosive as he judged to be sufficient, it would be objectionable for more

to be added, as alluded to in the eighth conclusion. He would therefore suggest, for the committee's consideration, the advisability of adding to the eighth conclusion the words—"but in view of the possible danger from over-charged shots this practice is not to be recommended."

Mr. J. L. HEDLEY (H.M. Inspector of Mines) asked Mr. Blackett to describe how he made his experiments upon stemming?

Mr. BLACKETT said he first placed an iron pipe (about 1 inch in diameter) on a hard surface, rammed in the clay with a piece of wood to the required length, and fixed the iron pipe into a machine (used for measuring the breaking-strain of wire-ropes). He was then able to apply pressure and to measure the force employed when the clay began to protrude. All the borings were similarly well-rammed with a wooden stemmer, and in all cases the readings of the dial were taken as soon as the stemming began to move.

Mr. D. A. LOUIS (London) asked whether any analyses had been made of the atmosphere in the tube after an explosion, for if even mixed with external air, so as to upset the proportions, nevertheless the character of the products of explosion under the existing conditions could be ascertained, and it would be interesting if only to compare them with the results of previous investigations of the same description?

Mr. BENEKÉ wrote that he was convinced that the committee had arrived at wrong conclusions with regard to the length of flames emitted by the various high explosives. According to Table IV.* bellite, securite, ammonite, roburite, carbonite, and ardeer powder were supposed to have produced flames varying in length from 10 to 36 feet, when fired unstemmed into air only. He maintained that such flames were impossible; the instantaneous flash-light from a shot fired in total darkness, through a long tube, with small sight-holes for observation, conveyed to many an unaccustomed eye the impression of enormous flames. This, however, was not so; reflection only was seen, as proved by hundreds of photographs taken of the length of flames produced by many high explosives. The actual flames were very short, often not more than 1 or 2 inches long, and it depended entirely upon the composition of the explosive, as well as upon the temperature of the flame, whether such short flames would cause an ignition of the gaseous mixture or of coal-dust. Again, in Table IV., flames from 10 to 62 feet long were supposed to have been seen when the shots were fired into mixtures of 4, 6, 8, and 10 per cent of coal-gas, and without igniting the inflammable mixture. The supposed flames could only have been reflection, as 6 or 8 per cent. of coal-gas could easily be

* *Report*, page 23.

ignited with an ordinary match, and certainly more readily by such enormous lengths of flames as those presumed to have been observed. In the mine, shots weighing from 6 to 16 ounces of explosives were usually employed, yet many of the committee's experiments were made with 1 to 1¼ ounces shots, exploded with a powerful detonator, which was only intended for use with much larger quantities. Consequently, many ignitions were recorded which could only be attributed to the powerful detonator, which increased the available amount of oxygen and generated more heat and a larger flame. It was impossible, therefore, to regard the results obtained as final or satisfactory.

Mr. F. BERKLEY said he did not consider that Mr. Blackett's experiments with stemming were applicable to the discussion, as he thought that stemming, which would resist sufficiently the force of an explosion, might show very little resistance to a steady push with a rammer. With dynamite, they all knew that, where it was applicable, water was a sufficient stemming, and, in the case of water, there would be no resistance to the rammer.

Mr. LARSEN said that if the experiments with explosives fired in the Trauzl cylinder were considered, it would be found that gunpowder fired by a detonator had less strength (36) than an equal volume of dry sand, surrounding a detonator alone (46).* The use of the Trauzl cylinder was very well known abroad, and it had never been regarded as a reliable means of testing the relative strength of explosives with different velocities of combustion. Its results had, however, been used as the standard of strength by the committee. On referring to the *Report*, he found that the charges of ardeer powder and carbonite used were from twice to nearly four times respectively the weight of those of bellite, securite, and roburite.† A weight of 3¾ ounces could not by any means be considered a severe test, but it was a comparatively severer one than that to which the other explosives were submitted. There were many engineers who had to daily deal with these explosives, and he thought their judgment as to their relative strengths would be much more valuable than the mortar test or the Trauzl cylinder; they would be able to state which was the strongest and how much stronger one explosive was than another. They would agree that most of the safety-explosives, which were used to a great extent in coal (at any rate in South Wales and Lancashire, if not so much in Durham and Northumberland), might be taken as interchangeable, and cartridges of one kind used in substitution for those of the same weight of another kind. He would therefore

* *Report*, page 17. † *Ibid.*, page 17.

suggest that the same weight of explosive should be used in the farther experiments and in much larger charges than had been used hitherto. By gradually increasing the charges, the limit of safety could thus be determined for each explosive. Similar experiments had been made on the Continent with charges as high as 16 ounces, without any stemming. Such charges, of course, gave a very heavy shock, and he understood that the committee did not care to incur the danger of bursting the cannon. This danger, of course, was a serious objection, but the cost of a new cannon should not be allowed to prevent heavy charges of explosives from being tested. With regard to the observations of flash and flame, he concurred in Mr. Blackett's remarks. The committee had stationed gentlemen, each at their particular window, to make observations independent of the others. No doubt this was a very good idea, but to show how easy it was to err in this matter, he might mention that in experiments which he had recently witnessed, twelve or fifteen people were looking at one place, and about half of them saw the flame and the other half did not. He was inclined to believe that there was very little difference in the actual composition of the explosives. The explosives were sampled from time to time by the Government inspectors and submitted to analysis in London, and any deviation from the terms of their manufacturing or importing licenses would render the licensees liable to penalties.

Mr. THOMAS BELL (H.M. Inspector of Mines) asked if he understood the last speaker aright that 16 ounces of explosives were fired without stemming, and, if so, with what object?

Mr. LARSEN said that such severe tests had been made: it being considered that an explosive which would bear an abnormally severe test would be safe under less severe conditions.

Mr. THOMAS BELL, referring to Mr. Larsen's remarks upon the observation of flame, said he understood that gentleman to say that there was only one pair of eyes to make each observation, but in the case of the committee's experiments there was a fresh set of observers every day, and before the experiments with one class of explosive were concluded possibly fifty pairs of eyes might have been employed to observe the results.

Mr. LARSEN said he did not wish to make too much of this point, but simply to endorse Mr. Blackett's remark that there was a difficulty in recognizing what was seen.

Mr. R. W. BERKLEY said that the results of the experiments of the French Commission showed that the greater the quantity of explosive

used the greater the danger. The Explosives Committee of the Institute seemed to have used rather small quantities, would it not be desirable in future experiments to use heavier charges? The pit-gas used in the experiments contained 18 or 19 per cent. of nitrogen. How did this compare with ordinary pit-gas?

Mr. SAVILLE SHAW said that the pit-gas used in the experiments contained 18 or 19 per cent. of nitrogen, and Mr. R. W. Berkley suggested that this gas might have perhaps some effect on the temperature of ignition. That point had, however, been settled by Messrs. Mallard and Le Chatelier,* who proved that an admixture of an indifferent gas, such as nitrogen, had not the slightest effect in altering the temperature of ignition of mixtures of pit-gas and oxygen; that pit-gas and oxygen had a definite temperature of ignition, and that the gaseous mixture could be diluted with an inert gas like nitrogen, and the dilution would not have the slightest effect upon the temperature of ignition.

Mr. J. L. HEDLEY (H.M. Inspector of Mines), in reply to Mr. Blackett, said that it was necessary to have a diaphragm in order to confine the gases to a certain portion of the tube; they could not divide the explosive chamber from the remainder of the tube in any other way. The paper-diaphragms were used in all the experiments when gas was required, and whatever objection there might be to the use of these diaphragms would apply equally in all cases. Mr. Blackett had referred to the wet stemming, but the stemming used in the experiments was not wet, it was "damp, puddled clay," not quite dry, but well-tempered, and before being put into the bore of the cannon, it had generally been surrounded with some dry clay to enable them to press the charge properly into the mouth of the cannon. He did not think that the steady pressure used in the experiments made by Mr. Blackett could be compared with the results obtained by a sudden and violent explosion. In the case of gunpowder, a suitable length of stemming must be used; but with high explosives a shorter length of stemming was sufficient. The experiments had proved that the difference (so far as safety from flame was concerned) between 2 inches and 8 inches of stemming was very little; and practical experience in the mine had also proved, time after time, that high explosives required much shorter lengths of stemming than gunpowder. Many comments had been made, in that hall and elsewhere, as to the small charges of explosives used in the experiments. He thought that when the weight of 8 ounces of gunpowder was first decided upon as a basis, it was because shots of that size were

* *Annales des Mines*, 1883, vol. iv., page 295.

used in this mining district. If that quantity of gunpowder were used, it was proper therefore when higher explosives took its place to make the experiments with the equivalent weights of each. He could not say whether different results would be obtained with heavier weights of explosives, for the committee had not a cannon suitable for that purpose at present. The observation of flame was a matter which the committee had considered of great importance, and the members of the committee had now had considerable experience. Although it was quite possible that anyone seeing a reflection for the first time, and, consequently, with an unaccustomed eye, might mistake it for a flame, he thought their experience qualified them to judge whether they saw flame or reflection, and so far as they had been able to prove they were far better able to distinguish between the two in the daytime than at night, for reflection could be seen very much farther in the dark. So far, however, as that part of the experiments was concerned, the committee were compelled to trust to their eyesight, for they had no other means of observation. They had done the best that they could, and he thought it could be safely said that the results recorded were thoroughly reliable. It was stated in the *Report* that the explosives might be defective, and Mr. Blackett suggested that the detonators might also be defective. That might be the case, but they were certainly justified in saying that the manufacture of explosives might be defective, from the varying results obtained. It was known and admitted by manufacturers that variations did occur in the composition of an explosive which might materially affect its action. Samples were therefore taken of each batch before placing it on the market, and, if found defective, it was condemned. A small quantity, however, could only be tested, and it was quite possible that some portion of the bulk might be inferior and the remainder good; yet the inferior portions might escape detection until it was brought into actual use belowground. He took issue at once with Mr. Blackett as to the defective mixture of the gases; such a defective mixture had not been found, and this statement was proved by the fact that when a gaseous mixture was not exploded by the shot itself it was immediately afterwards exploded by means of a match. Mr. Louis enquired as to analysis of the fumes; the committee had done nothing in that matter. Mr. Beneké alluded to the difference between flame and reflection and considered it impossible that they should see certain things, but that gentleman did not give the results of any experiments to show that his contention was correct. The committee's experiments proved that what Mr. Beneké considered

to be impossible, was opposed to the actual facts, as demonstrated time after time. Flame had been seen repeatedly in, and passing through, explosive mixtures without ignition of the gas, although the heat was much more intense than that of a lighted match, and on more than one occasion, the gaseous mixture became ignited at the far end of the chamber, with an appreciable interval of time between the ignition of the explosive and of the gaseous mixture; in such cases the effects of the explosion was of exactly the same nature as it would have been if the gases had been ignited at the far end of the chamber with a lighted match.

Mr. A. C. KAYLL said that Mr. Beneké in the previous discussion* had said that the ignition of the gaseous mixture was due to the detonator and not to the explosive; and that such ignitions would not have occurred if charges of 16 ounces and upwards had been used, as the gases of the heavier charges would have damped the flame produced by the detonator before they could reach and ignite the gaseous mixtures. He thought that view must be somewhat a matter of conjecture, and it certainly did not accord with the results obtained by the committee. Mr. Blackett agreed with the eighth recommendation of the committee as to miss-fires, but objected that it was dangerous to fire a second shot if employed in mines. If they got rid of the original charge by inserting a second charge in the hole, they were liable to a blown-out shot, because a double weight of explosives would be used to do the work, and Mr. Blackett thought that there was more danger. He thought that the danger was not so great as at first sight appeared, and certainly there was no extra risk of a blown-out shot, because if the original charge would act upon the coal and not blow out the stemming, double the quantity of explosive would the more readily so act. If the detonator was properly fixed and not disturbed by the action of stemming, miss-fires might occur from three reasons: (*a*) faulty explosive, the detonator being a good one; (*b*) a faulty detonator owing to the absence of fulminate, or the fulminate being inert the detonator was a dummy, the explosive in this case being good; and (*c*) the detonator wires being short-circuited or the flash not reaching the fulminate owing to faulty manufacture, the explosive in this case also being good. Supposing they got rid of those charges which had miss-fired by placing another charge in the same hole in front of the original one (instead of adopting the present system of making another hole). Taking them in rotation as above: (*a*) It would be seen by the disturbed state of the stemming that the detonator had fired. A fresh

* *Trans. Fed. Inst.*, vol. viii., page 234

charge would be placed in the same hole, but not of the same weight, as there would be less length of hole owing to the first charge being in its place. The firing of this second shot would most probably not detonate the first charge, as the explosive was faulty, and therefore the extra danger was almost *nil*. The hole, however, would be cleared of some if not all of the explosive, which would be scattered and rendered harmless. (*b*) The detonator being a dummy, the firing of the second charge might or might not detonate the first (if the explosive was a nitrate-of-ammonia compound it probably would not detonate it), but in this case also the weight of explosive put into the hole would be smaller than the original charge. (*c*) The second charge would detonate the first, owing to the detonator in that charge being a live one, but again the second charge would not be of the same weight as the first. The extra danger was certainly increased, owing to the double quantity of explosive, and some of the gases would have little or no mechanical work to perform. On the other hand, was not the danger greater under the system of making and charging a new hole, which might be at some distance from or near to the first hole? If at some distance from the first hole, the shock from the second shot might not detonate the first charge, and this charge in its entirety, with the live detonator affixed, might be buried in the fallen coal and be set off by a workman accidentally striking the detonator. Assuming that the second hole be made near the first, the shock of the second shot would most probably detonate the first charge, and there would then be two full charges doing the work originally intended for one. The coal being partly acted upon a moment of time before the detonation of the old charge, the heated gases resulting from this charge would escape through the fissures made by the new charge. If the explosive used was dynamite in any of its forms, he could not but think that it would be much safer to get rid of a shot which had miss-fired by means of a primary charge placed in the same hole in front of the original charge, than by adopting the method of making a new hole and running a risk of having a lump of dynamite buried in the coal or stone which might be filled into the tubs, passed over the screens into the waggon, and loaded into a ship. The risk of a blown-out shot was reduced to a minimum, if a sufficient holing were made and the quantity of explosive necessary for the work were used. It was improper workmanship and a desire for the impossible that gave rise to blown-out shots.

The PRESIDENT then read the following quotation from Mr. Kendall's paper on "Miss-fires":—

Two cartridges, without a cap or fuze, were put into the bottom of the hole. These were stemmed with a certain thickness of clayey stemming; another cartridge or half-cartridge with a cap in it, and fuze attached, was placed on the top of this stemming, and a farther lot of stemming, generally not more than an inch or two, was put over this last cartridge or half-cartridge. The primary stemming, that between the two lots of explosive, was tried of all thicknesses up to 14 inches, and in every case the whole of the dynamite in the hole was exploded, and the work intended to be done by it executed satisfactorily. In one experiment 5 inches of paper was put between the two lots of explosive and 2 inches of paper on the top of the last cartridge, no clay stemming whatever being used. The hole was a very strong one, in the middle of a narrow forehead, but the ground got by it was all that could have been expected if any amount or quality of stemming had been employed.

The lesson to be learned from these experiments is this: it is quite unnecessary to put more than 3 to 6 inches of stemming at the most into a hole, but if this were increased, say, to 8 inches in deep holes, so as to partly meet the prejudice of miners generally, yet even then in case of a miss-fire, all that has to be done is to put another cartridge, or part of one, on to the top of the stemming, and the first charge will be exploded in the manner described above. No unramming of a hole is necessary, and no pricker need be used, so that all the risks attending these two operations will be avoided.*

Mr. A. C. KAYLL said that Mr. Kendall's remarks applied to nitro-glycerine compounds, such as gelatine-dynamite, blasting-gelatine, and gelignite; nitrate-of-ammonia explosives could not be dealt with in the same way, as the original charge would probably not be detonated unless the shock of the new charge communicated it to the live detonator in the original charge, which in its turn might act upon that charge.

Mr. SAVILLE SHAW said that objection had been taken to the method of testing with leaden blocks. That method had been decided upon by the committee because it was most convenient and involved the least expenditure of time and money in procuring apparatus. And, after all, the conditions of firing an explosive were quite comparable with the conditions under which the explosive was fired in a mine. The method of testing with leaden blocks was to fire a small quantity of the explosive in a small hole. The explosive was surrounded with soft lead and tamped with sand, and the conditions were not altogether different from those prevailing in a mine, where they had the resisting coal or stone and the tamping. Of course, it only gave fairly comparative results with high explosives and strong detonation, and it was never intended that the results obtained with blasting-powder should be compared with those obtained from high explosives. He thought that too much stress had been placed upon this point, and that the method was a reliable one for comparing the detonating explosives. With reference to the observa-

* *Trans. Fed. Inst.*, vol. vii., page 608.

tion of flames from 10 to 62 feet in length passing through 10 per cent. coal-gas mixtures without ignition, some little explanation was necessary. The explosion of a gaseous mixture depended upon several factors. With regard to the temperature of detonation of the explosive, it seemed natural at first sight to suppose that if the explosive had a temperature of detonation higher than the temperature of ignition of the gaseous mixture, it ought in every case to fire it, but they knew that this was not so. There was no known explosive which had a temperature of detonation as low as the temperature of ignition of a mixture of pit-gas and air (which might be ignited by a temperature of about 670 degs. Cent.). All the high explosives had a temperature of detonation far above this, and yet it did not and should not follow, that they would ignite the mixture, because the length of time during which the hot products of combustion were in contact with the gaseous mixture must also be taken into consideration. Also as pointed out in the *Report*,* the experiments of the Prussian Fire-damp Commission showed that thin platinum wires melting at a temperature of 1,775 degs. Cent. could be melted in the midst of an explosive mixture of pit-gas and air, which had a temperature of ignition far below this, without causing its ignition, owing to the small volume of the heated body. The time during which the heated body was in contact with the explosive mixture had an important bearing; as also had the volume or bulk of the heated substance. If they took a white-hot body and plunged it suddenly into an explosive mixture, withdrawing it as suddenly, there would be no ignition, because the whole mass had not been raised to the temperature of ignition. In connexion with this, he might mention an experiment with gunpowder and gun-cotton frequently exhibited at lectures. The temperature of ignition of gunpowder was roughly 300 degs. Cent., the temperature of combustion of gun-cotton being 1,455 degs. Cent. One would naturally suppose that it would be utterly impossible to ignite gun-cotton in contact with gunpowder without firing it, yet it was possible to take tufts of gun-cotton, sprinkle them over with gunpowder, and after lighting the gun-cotton to find the grains of gunpowder lying unburnt. In that experiment, the time was too short for the high temperature produced by the gun-cotton to ignite the gunpowder. There were also mechanical causes of non-ignition. The ignited gases had so tremendous a velocity, that they did not allow time to fire the explosive mixture, even though the temperature of ignition of the gases was very much lower than the temperature of the hot gases which were passing through it. Therefore, they must

* Page 38.

consider not merely the temperature of detonation of the explosive as compared with the temperature of ignition of the gaseous mixture, but the velocity and also the volume of the heated gases which passed through the explosive mixture. A small quantity of an explosive need not necessarily explode the gaseous mixture, whereas a larger amount of the same explosive might do so.

Mr. W. C. BLACKETT said that to go fully into the question of stemming would involve a lengthy discussion, so he would therefore only answer one or two points. If there was so little importance to be attached to stemming, as some of the speakers implied, it seemed to him incomprehensible that the committee had used stemming at all, and a difference had been found by the committee between the use of stemming and no stemming. If it were proved that stemming was to some extent effective, it seemed to him to follow logically that the amount of stemming must have some importance. He was not prepared to say that this should follow a simple ratio, but it must have some effect. His own experiments were confirmed by those made a few years ago by Messrs. W. Foggin and M. Walton Brown, in which they used, unlike the present committee, seggar-borings which had a tendency to set, and they came to the conclusion that the length of stemming had a considerable effect on the safety of an explosive,* and he contended that if the most efficient material for stemming were used, it would have a decided effect on the safety of an explosive. Mr. Hedley said he (Mr. Blackett) used the term "wet clay," but the words he really used were those of the committee "damp puddled clay." He did not intend to state that explosives were not defectively mixed, but what he complained of was that the committee had come to the conclusion that the defects in explosives "appear to be due in some measure to defective admixture," but had produced no evidence whatever to show that this was so, and he considered that the committee should have recorded some facts proving their statement. As to plugged and unplugged detonators, he found on reference to the report of the French Commission, that—

The principal difference between the unplugged and the plugged detonators is that, in the latter, the fulminate placed at the bottom of the cylinder is almost covered by a small metallic bonnet, with an orifice at the top, which exposes the fulminate and allows firing to be effected. Moreover, the thickness of the metal is greater, and the fulminate, being more compressed, has a greater density. †

* *Trans. Fed. Inst.*, vol. ii., page 489.

† *Report of French Commission.* Translation, page 41.

In other words, the copper tube with the fulminate of mercury was stemmed. A little copper ring was inserted, and allowed it to be exploded in a very favourable way. Not only were plugged detonators used in the experiments of the French Commission, but the resistance of the copper case was increased by wrapping with wire. He was pleased to hear Mr. Kayll's remarks upon the eighth recommendation, as they added much information to that contained in the *Report*.

The farther discussion was adjourned.

The meeting then closed.

APPENDICES.

I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

NATIVE BISMUTH IN WESTERN SUMATRA.

Het Voorkomen van Bismuth op het Schiereiland Samosir [Tobameer]. By N. WING EASTON. *Jaarboek van het Mijnwezen in Nederlandsch Oost-Indië,* 1894, *vol. xxiii. technisch-en administratief Gedeelte, pages* 84-93, *and plate I.*

The announcement of the occurrence of native bismuth on the peninsula of Samosir attracted considerable attention in 1892. The metal is extracted by washing from a loamy sand, which fills up cavities, mostly closed, in a tufaceous sandstone occurring along the banks of a stream. There are indications of the natives having at one time worked the deposit. The sand of the actual river-bed yields only occasional lumps of bismuth, and its general mode of occurrence throws little light on the primary origin of the metal.

The aspect of the bismuth and its crystalline fracture suggest a previously molten condition. There are no traces of the minerals usually associated with that metal. It appears to be a secondary deposit consisting of nests of metal very dispersedly distributed. The cavities containing these nests are intimately connected with the structure of the tufaceous sandstone, and with the occurrence in it of pebbles harder than the rock itself.

Search was made for other likely localities in river-valleys, a search rendered in some cases nugatory by the floods consequent on heavy rain. The rivers carry bismuth where the tufaceous sandstone crops out, and by Hoetana Bolon the metal occurs in a pumice-bearing tuff which forms the walls of the ravine; but, on the whole, the results may be regarded as negative, and the important occurrences as restricted to the tufaceous sandstone-area lying between Si Déak and Sipakok. At present there can be no question of sale or export.

The hypothesis of the origin of the bismuth is much as follows. A liparite-lava in the course of eruption came into contact with metalliferous, particularly bismuth-bearing lodes, and the bismuth, on account of its easy fusibility, was separated from its associated minerals and carried along in the liparite-crust. As the eruption took place under water, the liparite was of a slaggy, pumiceous character, and the molten metal collected, therefore, in the cavities of the porous mass. This mass offered practically no resistance to erosion, and helped to build up the subsequently formed tufaceous sandstone in which the metal now occurs.

A geological map of Samosir Peninsula and the Toba district is given in the other volume (Wetenschappelijk Gedeelte) of the *Jaarboek* for the same year (page 99). O. S. E.

THE FRIEDEBERG APPARATUS FOR BURNING COAL-DUST.

Die Kohlenstaubfeuerung " Patente Friedeberg." *By* DR. B. KOSMAN. *Berg-und Huettenmænnische Zeitung*, 1894, *vol. liii., pages* 371-374, *and five figures.*

The apparatus consists of a vertical blast-pipe closed at the top and provided on one side with two circular openings. The vertical blast-pipe is covered with a revolving casing, fitted with pipes, so that when the apparatus is in use the pipes coincide with the openings in the blast-pipe. The blast is cut off and the feed stopped to the furnace by the whole apparatus being revolved around the blast-pipe.

The apparatus consists of a vertical hopper to receive the coal-dust, terminating in a box provided with openings at the bottom. Nozzles are arranged so that the blast moves and blows the coal-dust towards the delivery-pipe. Any pieces of coal in the dust fall to the bottom of the delivery-pipe, and may be removed by means of a movable slide.

Below the boxes and hopper is a horizontal blast-pipe, connected at one end with the vertical blast-pipe, and terminating in a nozzle opening into the base of the conical chamber attached to the front of the boiler-furnace. The upper and lower blast-pipes are fitted with throttle-valves by which the air-pressure may be regulated. The conical chamber attached to the boiler-furnace is fitted with a solid core, which secures the intimate and continuous mixture of the air and coal-dust fed into the furnace. The blast may be supplied by a Root or other blower, and requires from ½ to 1½ horse-power according to the size of the apparatus and the quantity of coal-dust fed into the furnace.

The maximum size of coal-dust should not exceed that passing through a 0·1 inch mesh screen; the best results being obtained with coal passed through a 0·04 inch mesh screen.

A Friedeberg apparatus has been applied to a Cornish boiler with a heating surface of 900 square feet, and supplies steam at a pressure of 90 lbs. per square inch to a 50 horse-power engine; the consumption of English small coal being 5,600 lbs. per day. The consumption of fuel before using the apparatus was about 6,900 lbs. per day.

Another Friedeberg furnace was applied to a tubular boiler supplying steam at a pressure of 105 lbs. per square inch to a 12 horse-power engine, the consumption of coal-dust being about 750 lbs. per 24 hours. M. W. B.

THE SOUTHERN LIMIT OF THE COAL-FIELD OF NORTHERN FRANCE.

Considérations sur la Limite Sud du Bassin Houiller du Nord de la France. *By* GUSTAVE F. DOLLFUS. *Annales de la Société Géologique du Nord*, 1893, *vol. xxi., pages* 332-342.

Recent work and newly-discovered facts all tend to confirm the mapping (by the French Geological Survey) of the anticlinal which forms the southern boundary of the coal-basin of the departments of the Nord and the Pas de Calais.

A boring at Bouchain, after passing through 24 feet of Pleistocene deposits and 252 of Cretaceous, struck Lower Devonian sandstones and slates. These Devonian strata dip very steeply to the south (60 or 80 degs.) Several accidents having taken place, the boring was stopped at 607 feet.

Another boring, at Noyelles-sur-Selles, 2¾ miles east of Bouchain, proved that beneath 10 feet of superficial deposits only 128 feet of Cretaceous intervened before the Devonian was reached. The sandstones and slates have much the same

character and dip as in the other boring. In October, 1893, the boring was still being carried on below 610 feet, but the expectation of the engineers, that they would strike a mass of Carboniferous Limestone and Coal-measures nipped in the great southern fault, had not been fulfilled. The levels of the Palæozoic rocks hereabouts agree exactly with the contours predicted by Mr. Marcel Bertrand.

O. S. E.

THE EXTENSION OF THE WURM COAL-FIELD.

Ein neues Steinkohlengebiet. By FRANZ BÜTTGENBACH. *Berg-und Huettenmaennische Zeitung*, 1894, *vol. liii., pages* 361-364, *with figures in the text.*

Workings for coal were begun in the Wurm basin in 1113, and mining industry has gradually and uninterruptedly developed in that district up to the present day. The boundaries of the coal-field westward of the great Feldbiss fault, which appears to strike north-west and south-east, were determined as far back as the sixteenth century, and up to 1846 that fault was regarded as the eastern limit of the coal-field. But certain deep borings put down about the above-mentioned year proved that the Coal-measures extend east of the fault, whose downthrow amounts to several hundreds of feet. And while the seams west of the Feldbiss fault were of meagre anthracitic coal, those east of it (worked near Merkstein and Höngen) were of open-burning bituminous coal: their stratigraphical identity has, however, been established, and another series of seams has been found at a higher horizon, seams which are missing west of the Feldbiss fault. In that westerly area, the measures were folded into synclinals and anticlinals, whose southern limbs were all but perpendicular, while the northern limbs had a comparatively gentle dip of 8 to 12 degs. The seams west of the Feldbiss fault have been long worked in the parish of Kirchrath, on the Dutch side of the frontier, and until recent years it was not thought that the coal-formation extended much west of that locality. But in 1870-79, 29 boreholes put down along the line of the Anstel Valley (Holland) touched the coal below a thick covering of drift, Tertiary beds, and Cretaceous. The Carboniferous measures were reached at depths varying between 131 and 656 feet, the coal-seams at depths between 164 and 755 feet, and the thickness of the latter varied between 12 and 60 inches. The Government of the Netherlands thereupon granted about a dozen mining concessions, but these fell through in 1892, and a new company, largely financed and managed by German capitalists, has now taken over some of the concessions, and has put down a shaft at Heerlen (Orange-Nassau). This place is in the centre of the new extension of the coal-field, and lies 5 miles north-west of Kirchrath, which used to be considered the extreme westerly limit. It is inferred that the lie of the seams will here more nearly approach the horizontal than they do in the south-east portion of the coal-field (*e.g.*, at Höngen, where the measures are folded into zig-zags), and the coal so far proved is bituminous. The author proposes to call this new extension, which covers an area of 29,652 acres, the "Limburg coal-basin," and remarks that its industrial importance is fully equal to that of the whole of the Wurm coal-basin so far known. But there is reason to believe that still another and vaster extension of the coal-field will shortly be revealed: borings near Hückelhoven, 15 miles north of Herzogenrath, have proved the existence of Coal-measures, and would thus enlarge the total area of the Wurm basin to 840 square kilometres (207,564 acres).

O. S. E.

COAL-FIELDS, DIAMOND MINES, ETC., IN DUTCH BORNEO.

Topografische, geologische, mineralogische en mijnbouwkundige Beschrijving van een gedeelte der Afdeeling Martapoera. By J. A. HOOZE. *Jaarboek van het Mijnwezen in Nederlandsch Oost-Indië*, 1893, *vol. xxii., pages* 1-431, *with figures in the text, eleven maps and six plates of sections.**

The district of Martapoera is in the Southern and Eastern administrative division of Dutch Borneo. It is bounded on the north by the Riam Kiwa river, which, after joining the Riam Kanan, becomes the Martapoera river. On the south it is shut in by the Bobaris and Meratoes mountains, while westward it stretches to the Java Sea. The district covers an area of 864,850 acres, and the population, almost entirely native (with a very small sprinkling of Chinese), numbers 90,000. Along the coast, and in the lower basins of the great rivers, the country is low-lying and swampy, but it rises inland in hills stretching away to the foot of the Bobaris mountains: between these and the Meratoes massif hilly country alternates with high ranges.

Regarding the Bobaris and Meratoes mountains and the intervening area as one massif, this is found to consist very largely of crystalline schists (quartz-, mica-, hornblende-, actinolite-, chlorite-schists, etc.), of serpentines and gabbros, while diabases crop out in dykes and bosses and sheets. Against this massif rest sedimentaries of pre-Tertiary age, covering all the country between the serpentine boundary-ridge of Bobaris and the hills of Tertiary coal-bearing sandstone. These pre-Tertiaries are mainly fossiliferous sandstones and conglomerates alternating with bands of black marl-slate and red, white, and grey limestone. Red and light-grey porphyrites intrude among these in dykes and bosses. Unconformably upon the pre-Tertiary rocks lie the quartzitic sandstones, and the claystones with bituminous coal of Eocene age, constituting regular ranges of low hills. Above the coal-formation come a series of marls, and then the Nummulitic Limestone: the thickness of the latter averages 7 feet and never exceeds 33. The Eocene is very extensively capped by drift and alluvial deposits. The drift containing diamonds stretches away north of the Maloeka river, along the north-western flank of the Eocene coal-formation, but no diamonds are found in the drift south of the Maloeka nor in the Tabanio river-basin. At some localities the drift rises to a height of more than 197 feet above sea-level. Pliocene strata with brown coals occur north of Martaraman, about 7 miles away from the hills of Eocene coal-bearing sandstone, and at Seboehoer.

It may be noted that the sudden bending in some places of the Eocene coal-bearing sandstones is due to the presence of sheets or bosses of augite-andesite. The pre-Tertiary sedimentaries almost certainly belong to the Upper Cretaceous, and include two distinct groups: the older shales, and the younger sandstones, conglomerates, limestones, marls, etc.

The Eocene formation is capable of subdivision into three groups: (*a*) Lower or Sandstone Group, with bituminous coal-beds; (*b*) Middle or Marl Group; (*c*) Upper or Limestone Group. The Bornean East Coast coals of Tertiary age may be classified according to their combined water as follows:—Coals with more than 20 per cent. of water, Pliocene; with from 15 to 20 per cent., Upper Miocene; with from 9 to 15 per cent., Lower Miocene; with from 3 to 7 per cent., Eocene.

The lithological characters, the fauna and flora of group *a* are described, and then follows a minute stratigraphical description of the principal coal-fields. These are (1) the Pengaron coal-field; (2) the Soengei Raja-Assahan coal-field; (3) the coal-fields between the Takoeti and the Riam Kanan river, including the

* *Trans. Fed. Inst.*, vol. iii., page 354, Plate XXI.

Djalamadi-Djabok coal-field; and (4) the coal-fields between the Riam Kanan and the Banjoe Irang river, and between the Banjoe Irang river and the Java Sea.

The younger Tertiary formations with brown coal occupy a comparatively small portion of the area under consideration. Analyses are given of eleven specimens of brown coal from the Assem-Assem river basin, the ash averaging 1·60, sulphur 1·03, water 22·6, and coke 45 per cent.; the ash of one of these was found to contain gold. Good briquettes can be made from the brown coals.

With regard to the bituminous coals, the Pengaron is a good coking variety, and averages, as to calorific effect, about 88, taking Newcastle coal as 100. Pyrites occurs very generally in it and in the Assahan coal, but in a state of rather minute division. Spontaneous combustion has never been known to take place with Martapoera coals, although in the Pengaron coal-field, for example, the small has lain stacked for years at a time. Fires have frequently broken out in the workings at Assahan, but are attributable to other causes. A very essential constituent of the Eocene coals of Borneo is resin, which is seen in nearly every lump of coal. A description is given of the methods of working, together with statistics of annual production, of the Orange-Nassau mine (first workings opened in 1848) at Pengaron, of the Assahan coal-mine, of the Julia Hermina mine at Kalangan, and of the Delft mine. The probable extension of the coal-fields is also discussed.

The diamantiferous sands and gravels occur along the valleys and in the river-beds of the area marked out by the Riam Kiwa, Riam Kanan, and Banjoe Irang rivers, and it is considered that the diamonds are derived from veins and lodes in the crystalline schists, more especially in the upper river-basins of the Riam Kiwa and Riam Kanan. These veins south of that region become less and less diamantiferous, and at the point where the gold diggings begin the diamonds are wanting altogether. The general occurrence of the diamonds and their physical properties are described, as also the methods of digging and washing the gravels. This section is accompanied by a table of the diamond claims in the Tanah Laut district, and tables of the finds in the Liang Anggang and Bentok diamond-fields. There are diamond-cutting works in Martapoera. An east-and-west line drawn across the Kobbok Hills, along the Seloeang river where the coal-bearing ridges slope away beneath the Quaternary deposits, forms the boundary betwixt the gold and the diamond-fields. The alluvial gold is supposed to be derived, not alone from veins and lodes in the crystalline schists, but from the contact-zones of these with (mainly) serpentine and porphyrite, and from the main mass of the schists themselves. The high-level auriferous deposits are extremely irregular in thickness and extent, but those at lower levels are more regular; the average thickness of the actual band of gold-stuff is 1 foot. The deposits are worked by pits and in open diggings known as *parits*. Tables are given of the chief gold-diggings in the Tanah Laut district and their production. The average richness of the diggings along the valley-sides is 1 carat of gold per square metre and ½ carat per cubic metre of the total mass of material. By the Chinese method of working the mean daily production per head is 4½ carats of gold. The richest *parits* are the Rangga, Rinaat, and Soengei Idjau. These, together with several other diggings, are fully described, and their productiveness is compared with that of other areas.

Platinum occurs in association with the gold and with the diamonds, and is apparently derived from the contact-zone of the serpentines with the crystalline schists. The results of the analyses of eight specimens show that the percentage of platinum in the ore varies between 57·13 and 82·60, of gold between 0 and 9·73, of iron between 5·45 and 10·67, and of copper between 0·13 and 0·73.

Iron (hæmatite) and manganese ores are found in several localities, but at present there is no likelihood of their being worked. O. S. E.

THE ORIGIN OF THE COPPER ORES IN THE TUSCAN SERPENTINE.

Die Kupfererzlagerstätten der Serpentingesteine Toscanas und deren Bildung durch Differentiations-processe in basischen Eruptivmagmen. *By* B. LOTTI. *Zeitschrift für praktische Geologie*, 1894, *pages* 18-19.

In Tuscany, under the heading "serpentine" or "ophiolite" are included (1) serpentine proper with its parent-rock lherzolite; (2) gabbro or euphotide, and (3) diabase. These are all of eruptive origin and of Eocene age; they occur in close association one with the other, and always preserve the same relative position, the diabase being on the top, the gabbro below it, and the serpentine and the lherzolite lowest of all. Moreover, the gabbro is seen in places to cut through the serpentine-rock, and the diabase cuts through both, wherefore the author infers that these rocks are the product of two closely successive eruptions.

The commonest ores are iron and copper sulphides; blende and galena seldom occur. Magnetite, as in the Isle of Elba, is common enough, but not in workable quantities.

The copper ores occur chiefly in the gabbro, dispersed in small particles through the mass of the unaltered rock, or forming lodes in its fissures. More frequently they are found in spherical masses, of diameter varying from a few inches to 3 or 4 feet, in a steatitic matrix, which is the decomposition-product of the gabbro.

In accordance with Prof. Vogt's views on the differentiation of eruptive magmas, the author believes that these spherical masses were formed in the process of differentiation of the original magma, in the same way as basic complexes separate out from acid rock-magmas. To the same cause, rather than to the determining influence of specific gravity, he attributes the accumulation of ores in the contact-zone, that is, in the gabbro lying between the serpentine and the diabase. So far from the decomposition of the gabbro having induced the concretion of the spherical masses, it is probably those spherical masses which have, where present, hastened the decomposition of the gabbro. O. S. E.

THE COPPER MINES OF THE PAMPA CENTRAL.

Viaje à la Pampa Central. *By* J. B. AMBROSETTI. *Boletin del Instituto Geográfico Argentino, vol. xiv., pages* 342-358. *Buenos Aires.*

The mines are situated thirteen miles south of the Sierra de Lihué-Calel, and belong to the *Sociedad del Mineral de la Pampa.* The ore-deposits were discovered by Mr. Tomás Bovadilla, who came thither from Chile, on the faith of an old parchment of the Jesuit Fathers, describing their itinerary from Valdivia to Paraguay. Much of the copper ore so far extracted had been sent experimentally to England. The surrounding country is a desert, covered with scrub, and the nearest water-supply is from a well sunk at Peña Verde, 3¼ miles south of the mines. This yields slightly brackish but drinkable water. Rain-water is stored in a pit of the Dos Chilenos mine.

The eighteen mines which have been started are worked by means of shafts, out of which the ore is hoisted with the help of hand-windlasses and in adits following the course of the veins. From the adits the ore is laboriously brought out in leathern bags on the shoulders of workmen known as *Apires.* In one working-day a good miner is reckoned to drill and fire with dynamite six holes 8 to 12 inches long. Most of the veins are capped by a ferruginous layer, which serves as roof. Thus, at the Flor de la Pampa mine, the cupriferous vein, 10 feet thick, is encased by ferruginous rock, whose contact-surfaces are perfectly smooth, and allow of the

ore being detached without the slightest difficulty. The district is one of plutonic and metamorphic rocks. In the north crystalline mica-schists occur, which it is suggested are the result of the metamorphism of granite by the intrusion of huge masses of quartz. The granite graduates into aplite and greisen. There are also quartzites cleaving vertically, sanidine-rhyolites, and highly garnetiferous eclogites. Copper silicate is disseminated through the quartzite in impregnations, encrustations, and veinlets, accompanied by specular iron ore. Copper also occurs in the form of auriferous and argentiferous oxides and sulphides. Assays made of ores taken from five mines show percentages of metallic copper varying from 3·92 to 7·40 (Dos Chilenos mine) and of silver varying from 0·0015 to 0·0095 (Flor de la Pampa mine). The complete analysis of a very rich sample from the Elisa mine gave the following result:—Copper (as oxide and sulphide), 36·33 per cent.; silver, 0·0102 per cent.; and gold, 0·0010 per cent. Mr. Franchy's theory of the genesis of the Lihué Calel copper silicate is that the copper originally existed in the form of pyrites. By decomposition of the portions nearest the surface, the pyrites was oxidized to soluble sulphates. The sulphates in solution entered into reaction with the lime-silicates contained in the felspars of the adjacent rocks, producing silicate of copper, which was then deposited in the form in which we now see it. It may therefore be predicted that, as the workings are pushed deeper down, copper sulphides will be struck; and, in fact, this prediction has already been verified at the Dos Chilenos mine, where there is a shaft 115 feet deep. Samples taken from 92 feet down were rich in erubescite (bornite). O. S. E.

THE DIAMOND-FIELDS OF LANDAK (WESTERN BORNEO).

Geologisch-mijnbouwkundige Opneming van een Gedeelte der Westerafdeeling van Borneo. Verslag No. 11. Het diamantvoorkomen in Landak. ANON. *Jaarboek van het Mijnwezen in Nederlandsch Oost-Indië,* 1894, *vol. xxiii. (technisch-en administratief Gedeelte), pages* 94-130, *and plate II.*

A topographical description is given of the district, which is elucidated by a map of the Landak river and its tributaries. The rapids, numerous in all the streams except the Behe, constitute a great obstacle to transport. Thus, to take one example, along barely 33 miles of river there are no less than seven portages.

The diamonds occur in lenticular quartz-gravel deposits called *areng*, of very variable thickness (4 inches to 8 feet); but the thickness appears to have no connexion whatever with the richness of the deposit in diamonds. The quartz-gravels lie in most instances directly upon rock in place; they have often, above or below, a thin hard layer of brown iron ore, and lumps of ferruginous conglomerate are often dispersed about in them. Flakes of mica, magnetite, and pyrites are abundant. Very hard pebbles of various colours, which the Malays call *leboer*, the author suspects to be corundum: in association with these diamonds always occur. The author describes the *leboer* under four groups, and calls attention to a similar occurrence in the Brazilian diamond-fields.

The whole aspect of the diamantiferous deposits suggests that they were laid down by the Landak river in times when it flowed at a far higher level than now; and the fact that diamonds have been hitherto found only at a short distance from this river, and not along its tributaries, leads one to infer that the matrix-rock should be sought in the upper Landak basin itself.

The rocks of the country are mainly soft, yellow-brown sandstones, interbedded with thinner argillaceous layers. Hard bands of a more quartzitic or siliceous character are seldom met with. The strata of this so-called "Behe complex" are

[illegible]

[illegible] Compound. By [illegible]

[illegible] the value of a steam-jacket [illegible] its value in multiple expansion [illegible]. He therefore [illegible] some careful [illegible] engine of 625 nominal horse-power, with

compound cylinders. A full description of the engine, and of the manner of making the experiments is given, also of the rehearsals of the actual experiments which he was careful to have in order to avoid any hitch in the delicate work of measurement and recording.

He gives the state of opinion upon the subject as varying from Prof. Unwin's dictum that "there exists no carefully conducted experiment which proves that the jacket causes a loss," to the opinion of those who hold that the steam-jacket caused a positive gain of 16 to 25 per cent., while others believe that the gain varies as the need of the engine, and is beneficial as preventing the accumulation of water in the cylinders than in any other way, and that there would be no use for it if the steam was, and remained, dry. The conclusion the author came to at the end of his experiments was that in a compound engine the condensation of steam at its admission into the small cylinder was much less than in a simple engine, and the quantity of water present at the end of the stroke was less also. The jacket was therefore not so necessary, and it was less efficacious in compound engines than in simple engines. When the jacket was heated it gave a gain of 3·7 per cent. of steam consumed, when it was there but not heated the gain was 6·6 per cent. The best result was obtained by suppressing the jacket of the receiver; from the point of view merely of the amount of steam used, the receiver-jacket was condemned; its only use was in the increase of work it produced, but it charged too much for the service it rendered, for it condensed 8 per cent. of steam, while only 6 or 7 per cent. was gained at the piston. But the jacket on the big cylinder was useful, because the services which it rendered were greater than their cost. W. M.

THE METHODS ADOPTED IN EXPLORING THE KARWIN MINES.

Zur Gewältigung der Karwiner Gruben. By R. LAMPRECHT. *Oesterreichische Zeitschrift für Berg-und-Hüttenwesen,* 1894, *vol. xlii., pages* 540-541 *and plate XX.*

The means employed for clearing the Karwin pits, in which the disaster of June 14th, 1894, occurred, may be classified as follows:—

(1) Damming-off of all the levels opening into the Franziska, the Carl, and the Johann shafts, in close proximity to the shaft, with the help of respiratory apparatus. (2) The ventilation of the above-mentioned shafts; and, finally (3), the direct advance from all three shafts against the inflammable gases, coupled with the advance of a current of fresh air. This last operation to be, in case of need, facilitated by the piercing of boreholes from the surface.

Turning our attention to (1), the apparatus used in the operation of damming-off is figured in the plate which accompanies the original paper. To enable the workmen to set to work in a shaft filled with irrespirable gases, the air needful for breathing was led to them from the surface by an indiarubber hose. Air at a pressure of four atmospheres was forced into a receiver, and was led thence by an air-pipe to the reduction-valve. Through the hollow axle of the hand-windlass, the air at the reduced pressure of 1·1 atmospheres was led into the main indiarubber hose, which passed over a pulley to the cage. Here the main tubing branched into three lateral tubes led over the drums. Two tubes (for the masons) were 200 feet long, while the third (for the use of the signalman) was only 66 feet long. On account of its great weight, the main hose (820 feet long) was clamped in lengths of 164 feet, together with the electric signalling-wires, by easily displaceable clamps to the winding-rope. The workers were equipped with the Bremen respiratory apparatus, consisting of a helmet with indiarubber tubing. The

wearer could see through a glass plate in the helmet, so arranged as to be removed without difficulty. The air for breathing purposes, the pressure of which owing to the length of the main hose was reduced to 0·6 atmosphere, was led in at the neck of the helmet and divided into three channels, which terminated at the mouth of the wearer. The respired air was expelled through two valves placed one on either side of the helmet. The men had each a Bristol electric lamp secured to their bodies. Moreover, in the cage there was a supplementary air-reservoir, which was supplied from a branch pipe. The air required for the Galibert air-bags was taken from this reservoir.

Communication was ensured by means of the electric signalling-cable, which ran over a windlass and over a pulley to a signal-bell. As it was possible that through an accident the supply of air from the compressor might be interrupted, four air-pumps which could be easily brought into connexion with the rest of the system were held in reserve. In case of extreme danger, so soon as the signal was given, the ventilator of a shaft which communicated with the shaft undergoing clearance could be set at work. The operations were conducted only during the day. The workmen had shifts of three hours, and were then replaced by a fresh lot of men. The author noted from personal observation that after their three-hour shifts the men left the shaft without showing the slightest signs of exhaustion.

As soon as they stepped on to the cage to go down, the hatch closing the top of the shaft was drawn aside, and closed again immediately the cage had passed below ground. Above bank stood in continual readiness the directing engineer, the doctor, four men at the air-tube windlass, two men at the electric cable windlass, three men at either side of the hatch-shutter, one man at each of the four reserve air-pumps, one man at the signal communicating with the ventilator, and two men at the second staging. The last-mentioned guided the winding-rope, with the main tubing and the electric cable clamped to it, through their hands, so as to be able to check any backward motion which might occasion a rupture of the air-tubing. The cage travelled as slowly as possible in the shaft. At nearly every 100 feet signals were exchanged between the pit and the bank to make sure that all went well. The code of signals was as follows:—

. Stop; . . Let go cage; . . . Draw up cage; . . . . Not much air; . . . . . . Don't understand; — . . . . Signal from bank that the workmen were to come out of the pit; — All's well, from below; — — All's well, from above; and — — — — — Help wanted.

It hardly falls within the scope of the present communication to explain in detail how account had been taken with an all but exaggerated minuteness of every accident likely to endanger the lives of the miners. And yet during the author's stay in Karwin one man was hurt. He broke the pipe which communicated with his helmet, and fell down insensible. His comrade tried in vain to press between his clenched teeth one of the two reserve-pipes from the Brass respiratory apparatus. The signal was, therefore, given to bring him to bank, and he was there restored to consciousness with the help of the doctor.

In the first half of September the chemical composition of the gases in the Franziska shaft was as follows:—Carbon dioxide, 3·5 per cent.; oxygen, 0·8 to 1·5 per cent.; methane, 58 to 60 per cent. The remaining gas was mainly nitrogen; scarcely a trace of carbon monoxide was noted. After the complete damming-off of the levels opening into the Franziska shaft, zinc pipes were put down to ventilate the shaft.

Thereafter began the advance against the inflammable gases, coupled with the introduction of a fresh air-current controlled by suitable brattices. Before breaking

through the dams air-doors were built up about 6½ feet apart. Exactly the same means were employed in clearing the Carl and the Johann shafts. At the latter they were under the necessity of first getting out, by means of a derrick, the winding-cage which had been jammed in the shaft as a result of the explosions.

O. S. E.

ORIGIN OF THE SECULAR ELEVATION OF THE LAND IN SCANDINAVIA.

(1.) *Preuves et causes du mouvement lent actuel de la Scandinavie.* By A. BADOUREAU. *Comptes rendus de l'Académie des Sciences*, 1893, *vol. cxvii., pages* 767-769, 874. (2.) *Étude sur le soulèvement lent actuel de la Scandinavie. By* A. BADOUREAU. *Annales des Mines*, 1894, *series* 9, *vol. vi., pages* 239-275, *figures in the text and plate XIV.*

In these remarkable papers, the results of a journey to the Scandinavian shores in 1892, the author first points out that the causes of variation of the sea-level compensate one another in such wise that most geological observers regard the sea-level at any given point as constant, and they measure by it the position of the neighbouring lands when they proceed to determine whether those lands are undergoing gradual subsidence or elevation.

He enumerates in great detail the following proofs that the Scandinavian peninsula, as a whole, is rising:—

1. *Historical.*—The port of Luleå, founded by Gustavus Adolphus, is now far inland; the Stœstsund channel and the harbour of Landskrona have been gradually shallowing; 99 bench-marks placed on the Swedish and Finnish coasts since 1730 show an average rise of 0·79 inch per annum; 27 bench-marks placed on the Norwegian coast near Cape Lindesnaes in 1839, and observed again in 1865, also showed a rise.

2. *Zoological and Palæontological.*—The lakes of Finland and Scandinavia, besides a freshwater fauna of recent importation, contain species regarded as the residue of a cold salt-water fauna, which has gradually adapted itself to the new environment. This fauna includes a mammal (*Phoca annelata*) restricted to the Finnish lakes, fishes, and crustacea; and it is inferred that these lakes, before the elevation of the intervening land, communicated with the White Sea. But ere that communication was interrupted, these old fjords became freshwater lochs, much in the same way as the upper extremities of the Norwegian fjords nowadays lose their saltness. Rain, river, and infiltration-waters came in, freshwater ice formed on the surface in the winters, and the deep, dense, salt-water flowed away to the sea.

The recent coral termed by Linnæus *Oculina prolifera* lives at depths averaging 600 to 1,800 feet, but remains of it have been found by Sars in the Christiania fjord, from 420 feet up to sea-level. And in the island of Barholmen it occurs up to nearly 100 feet above sea-level, associated with remains of the bivalve *Lima excavata*. This would prove a rise of at least 650 feet during recent times.

3. *Geological.*—A brief sketch is first given of the successive glaciations and movements of submergence and elevation in Scandinavia from the commencement of the Quaternary period. Attention is then drawn to the old shore-lines now raised as terraces 600 feet and more above sea-level (raised beaches, cliffs of erosion, old river-deltas). In Southern Sweden, moreover, there are deposits of inter-Glacial coloured clay and post-Glacial white clay, which prove that the sea at two distinct periods formed a "sound" from Stockholm to Uddevalla, across what are now Lakes

Wener, Hjelmar, and Maelar. The *åsar* or eskers, being supra-glacier river-alluvia (*i.e.*, derived from torrents flowing on the surface of the glaciers), are not regarded as throwing any light on the present subject.

Conclusions.—The gradual elevation being demonstrated by these accumulated proofs, an enquiry into its origin has impelled the author to agree with Messrs. Drygalski and de Lapparent that the phenomenon is due to the warming of the earth-crust, which was either a result or a cause of the disappearance of the ice. During the last glaciation, Scandinavia and Finland were covered by an ice-cap 950 miles or so in diameter, and the temperature of the soil beneath it could, of course, never rise above 32 degs. Fahr. Now the mean annual temperature of the same area of surface-soil at the present time is 37·5 degs. Fahr.; and, taking into account the linear coefficient of expansion of the rocks, this would allow of a rise of 750 feet at the central point. De Geer's map of contour-lines of equal elevation (*isoanabases*) shows that the conditions of Scandinavia almost exactly correspond to the requirements of the theory. The state of equilibrium has not yet been attained, and the ascensional movement of the Scandinavian peninsula is still going on, but at a lessening rate.

A list of the more recent standard works on the subject accompanies the second paper. O. S. E.

GEOLOGY OF BALIA MAADEN IN ASIA MINOR.

Die geologischen Verhältnisse der Umgebung von Balia Maaden im nordwestlichen Kleinasien (Mysien). By GEJZA VON BUKOWSKI. *Sitzungsberichte der kaiserlichen Akademie der Wissenschaften: Mathematisch-Naturwissenschaftliche Classe,* 1892, *vol. ci., pages* 214-235, *and plates I.-II.*

In this district argentiferous galena, which occurs at the contact of eruptive dykes with Carboniferous Limestone, has now been for several years worked by the Laurion Mining Company of Greece, under a concession from the Turkish Government. The chief workings are at Ari Maghara and Kodja Maghara, where suitable plant for cleaning the ore has been erected. After the preliminary cleaning it is sent by waggon or on the backs of beasts of burthen down to the coast at Aktchai. Thence it is shipped to Laurion for treatment at the smelting-works there.

Fossils show that the rocks of the district are partly of Triassic, partly of Upper Carboniferous (marine equivalents of Coal-measures) age. A short summary is given of the literature dealing with Carboniferous formations in Asia Minor.

The oldest stratified rocks are Carboniferous; they crop out chiefly in the south and east of the Balia Maaden district, and form the range of Aktchal Dagh (2,000 feet above sea-level). They comprise massive limestones of colour varying from light grey to black, dark-grey sandstones, and bluish-black shales. The sandstones and shales are subordinate members of the formation, and are repeatedly intercalated in the limestones. All these rocks have apparently been much disturbed, folded, and contorted. In a general way the strike of the Carboniferous rocks of Balia Maaden is from south-west to north-east, and this appears to hold good for the Triassic formations also.

The limestones are in some localities distinctly crinoidal in others foraminiferal, and in others again corallian and brachiopodal, but the actual succession of these different fossil-beds is difficult to determine on account of the above-mentioned

highly disturbed condition of the strata. The sandstones are apparently unfossiliferous, and in the calcareous shales only a few unrecognizable bivalves have been found.

The Lower Triassic consists of greenish-grey sandstones and conglomerates, and seems to be invariably marked off by a basement-conglomerate or extremely coarse grit, which, at its very lowest horizons, contains pebbles of the foraminiferal (*Fusulina*) limestones and Carboniferous sandstones. It is in some places seen to be plainly unconformable upon the Carboniferous. The Triassic sandstones become finer and finer-grained and more argillaceous as one goes upward—geologically speaking—in the series, and they finally merge into the greenish-black shales of the Upper Triassic. These are extremely rich in fossils. The dips change in so puzzling a way that in several localities the Trias appears actually to underlie the Carboniferous. The eruptive rocks of the district cover a large area in the north-west, and are mainly augite-andesites. In the neighbourhood of the Kodja Maghara mine the andesite shows a beautiful columnar structure. O. S. E.

ON ROLLED FRAGMENTS OF ROCK IN COAL AND ROLLED FRAGMENTS OF COAL.

(1.) *Sur des cailloux roulés de quartzites rencontrés au mur de la couche Grande Moisa du charbonnage de la Haye à Liége.* *By* MAX LOHEST. *Annales de la Société Géologique de Belgique*, 1893-94, *vol. xxi., pages lviii-lxi.* (2.) *A propos des cailloux roulés du houiller.* *By* G. SCHMITZ. *Ibid., vol. xxi., pages lxxi-lxxv.* (3.) *By* AD. FIRKET. *Ibid., vol. xxi., pages lxvi-lxxi.* (4.) *By* MAX LOHEST. *Ibid., vol. xxi., pages lxxxv-lxxxix.*

(1.) These pebbles were found on the floor of the Grande Moisa seam at a depth of 2,022 feet. They are rounded fragments of fine-grained quartzite coated with a brilliant black layer showing striae. Under the microscope sections show rounded, sometimes angular, grains of quartz, cemented by quartz often containing carbonaceous or ferruginous matter. This structure shows that they are not concretions. No similar quartzite is known in the Coal-measures nor in the pebbles of its conglomerate. The presence of these pebbles is considered to be contrary to the theory of formation in place.

(2.) Pebbles are usually found in, or at the bottom of, the coal-seam, and not in the roof or neighbouring rock, where nodules of carbonate of iron are often found. The coating of carbonaceous matter found on the pebbles was accounted for by long transport in the midst of vegetable matter. It was concluded that the presence of pebbles supports the hypothesis of transport for the generality of the sediments of the Coal-measures, but not for the floors of the seams. Why not, it was asked, admit the accumulation of vegetation *in situ* in lagoons bordering the Carboniferous continent while rivers transported vegetable *débris* into the same?

(3.) Rolled pebbles have been found in the roof of the Crusny seam at the Plancher de l'Espérance colliery at Montegnée. From their form, they may have been fossil fruits filled with fine sediment. In the Saint Victor colliery at Turon there is a coal-seam formed of true coal-pebbles cemented together. The formation of such a seam could only be explained by denudation and transport.

(4.) It is suggested that the beds of coal-pebbles were originally beds of wood-pebbles. Such beds of rolled fragments are well known, and occur, for example, in the clays of Andenne, and in a modern fluviatile formation in the neighbourhood of Bayards (Liége). G. W. B.

CONDITION OF GOLD IN VEINS.

On the Condition of Gold in Quartz and Calcite-Veins. By A. LIVERSIDGE. *Journal of the Royal Society of New South Wales*, 1893, *vol. xxvii., pages* 299-303.

As a rule, the gold contained in massive quartz was free from any trace of crystalline form, and the larger the fragment the less crystalline form it presented. Crystallized gold was not usually met with in reef-quartz, but rather in the upper portions of the ferruginous and argillaceous casing of the reef and in the detritus near its outcrop. When the gold occurred in a soft matrix like calcite, clay, or serpentine, it was very often crystallized, as also when it occurred in cavities, such as those left by the removal of iron pyrites. G. E. C.

THE ORIGIN OF GOLD.

Analyse d'un mémoire de M. Noguès sur la genèse de l'or. By F. LAHILLE. *Bulletin de la Société d'Histoire Naturelle de Toulouse*. 1892, *vol. xxvi., pages xxxi. and xxxii.*

Gold had been brought into its present deposits by the eruption of pyroxene-hornblende rocks (diorites, amphibolites, diabases, etc.), not in the condition of metallic vapours, nor by means of siliceous solutions, but in combination with iron and copper sulphides, arsenides, etc. On the subsequent decomposition of these the gold had been set free. Thus in specimens of dosimose (natural arsenio-sulphide of nickel) containing an appreciable proportion of combined but not visible gold, the mineral was oxidized to an arseniate, and the native gold was then observed in the free state. Diorites containing titaniferous magnetite were also pyritous and auriferous. The auriferous black sand of the Sierra de Peñaflor was derived from the denudation *in situ* of pyroxene-hornblende rocks; the crystals of gold, zircon, rutile, and pyrites which occurred in it had preserved their crystalline form intact.

O. S. E.

THE ORIGIN OF GOLD NUGGETS.

On the Origin of Gold Nuggets. By A. LIVERSIDGE. *Journal of the Royal Society of New South Wales*, 1893, *vol. xxvii., pages* 303 *to* 343.

The paper gives details of a large number of experiments made with the view of determining whether a nucleus of gold immersed in a solution of gold, and in the presence of such substances as are likely to be met with in nature, would increase in weight. This was proved to be the case, although other experiments showed that a gold nucleus was not increased in weight in the presence of organic matter, as had been so often stated. Prof. Liversidge, however, expressed his conviction that large nuggets had not been formed from solution. He questioned whether the common assertion as to the greater fineness of nugget as compared with vein-gold had any foundation in fact. With fine alluvial gold there was such a difference, possibly because the silver and other impurities had been removed by solution owing to the larger relative surfaces exposed.

Gold was present in meteoric waters (though no absolute chemical proof had been brought forward), because it was found in recently-formed pyrites, etc., where it must have come from solution. Furthermore, large nuggets could be artificially produced by following the methods used in his experiments. In places gold was probably being so deposited at the present day, but the large nuggets had not been formed *in situ*. With gold grains and dust the case might be different, on account of the much greater surface exposed. G. E. C.

THE RELATIVE ABUNDANCE OF GOLD IN DIFFERENT GEOLOGICAL FORMATIONS.

By W. P. BLAKE. *The Engineering and Mining Journal (New York)*, 1892, *vol. liii., pages* 348-349.

The age of the chief gold-bearing slates of the central gold region of California, where gold was mined in greater quantity than ever before, was for a long time in doubt. The dogma of the Lower Palæozoic age of most of the gold rocks of the world predisposed observers to regard the auriferous slates as Palæozoic. But about the year 1864, the author had the good fortune to find Mesozoic fossils in the midst of these slates, and thus removed all doubt of their true horizon. These fossils were *Ammonites* in the slates of Placer county, near Colfax; *Belemnites* and Jurassic bivalves in similar slates on the Mariposa estate, Mariposa county, and contiguous to the great gold-quartz vein known as the mother vein of California.

Thus the Secondary age of the chief gold-bearing slates of California was established. In the great belt of Jurasso-Triassic, and perhaps, in part, Lower Cretaceous strata, enfolded in the western flanks of the Sierra Nevada, were found the strongest, richest, and most productive gold-quartz mines and placer-deposits of California. The mother vein at Carson Hill, in Calaveras county, had yielded some of the heaviest masses of gold ever taken from veins.

The occurrence of gold in California was, however, not confined to any one geological horizon. It was found in close contiguity to limestone of Carboniferous age, as early shown by Dr. Trask, and no doubt in the older rocks of the Sierra Nevada lying parallel with the chief auriferous deposits. Thus at Hite's Cove, some miles west of the locality of the Jura Trias fossils of Mariposa, there was an important gold-bearing vein near a stratum of limestone in which the author found encrinal stems, and which was no doubt Upper Palæozoic. But these older strata in California have never yielded gold so generally and in such profusion as the newer beds farther west of them.

On the other hand, some of the most valuable gold-mines did not occur in stratiform rocks. The celebrated veins of Grass Valley, California, which have been worked continuously for over forty years, are in crystalline granitic rocks of uncertain age. The great Comstock lode in Nevada, which had added so many millions to the world's supply of gold as well as silver, was in crystalline rocks which, however, were probably altered Mesozoic beds. The gold of the Deep Creek region, Utah, as the author has elsewhere shown, was in altered Carboniferous Limestone, thus being in Upper rather than Lower Palæozoic. J. W.

GOLD-BEARING ROCKS IN HONDURAS.

Esquisse géologique et minéralogique du District aurifère de Santa Cruz, Honduras (Amérique Centrale). By ALEXANDRE J. BOURDARIAT. *Bulletin de la Société Belge de Géologie*, 1893, *Mémoires, vol. vii., pages* 35-40.

On the Atlantic watershed the auriferous deposits occur in gneiss, and on the Pacific watershed in trachytes. The gold in the former appears to be contemporaneous with certain diorite-outcrops, while the auriferous deposits in the trachytes show a greater abundance of gold and at the same time a larger percentage of silver ore. The richest mines in the country are those of Rosario, where the eruptive masses injected with rhyolite form the predominant rocks of the district. The annual production at these mines has continuously increased since 1887, when it was valued at 650,000 dollars. In the district of Villa Nueva, worked by the San Martin Mining Company, the gold and silver-bearing veins which

traverse the trachytes are characterized by the presence of an extremely friable, whitish-grey, talcose, clayey rock, containing small fragments of broken, highly siliceous rock, and charged with a quantity of gold and silver sulphide. This is locally nicknamed *jabon* (soap), and was the only stuff worked in the olden days by the Spanish miners. Elsewhere, as at La Concepcion mine, the veins become distinctly quartzose with a high gold and silver percentage.

Along the base of the Sierra del Spiritu Santo are ranged a whole series of gold-mining concessions. These have all been worked for periods varying from three to six years, after which, in most cases, mining operations have been stopped, the only really successfully-worked concession being that of Santa Cruz. It is to the description of the Santa Cruz district that the paper is mainly devoted.

Here the gold-quartz veins traverse schistose coarse-grained gneisses. Numerous hornblende-diorite dykes cut through the gneisses, and are always slightly auriferous. They appear to influence the quartz-veins (which they do not invariably traverse) in very different ways; sometimes the veins appear to grow richer near the dykes, sometimes poorer. The whole system of rocks has been much dislocated by steep faults. Six groups of veins are recognized in the Santa Cruz concession, and crop out over a fairly extensive area. Thus the outcrop of the Mandingua vein runs north-east and south-west for more than 1¼ miles, then disappears for a time, to crop up again in the Camelote Company's concession. All the veins are of the same age and of concretionary origin; they vary in thickness from 19 inches to 16 feet, frequently broadening all of a sudden into "rollings" where the quartz envelops lenticular masses of gneiss completely isolated from the country rock. But instead of becoming, as one might expect, richer in gold in these "rollings," the quartz appears to get charged with argentiferous galena. Small white "specks" of felspar are an invariable indicator of gold in the greenish-grey quartz of Santa Cruz. The band of reddish "crushed rock" which mostly runs parallel to the compact quartz is often the richest of the two in gold. The accompanying ores are sulphides of iron and lead, grey copper ore, mispickel, and natural alloys of gold with silver, platinum, and rhodium. But out of every 100 parts of gold in the vein, only 15 to 20 parts are, as a rule, combined with sulphides, the remaining 80 or 85 parts being free gold. The precious metal is, however, rarely visible to the unaided eye.

The quartz is crushed in contact with water and quicksilver in a 30 stamp-battery, set up on the Californian system. Such ores as are refractory to direct amalgamation are collected in the Fruc-Vanner apparatus, and roasted for eight hours, during which operation they give off the contained arsenic and sulphur. They are allowed to cool, being subsequently treated in the amalgamation-pan. Even then difficulties arise; metallic arsenic in the form of fine dust encrusts the quicksilver, and impedes the process, wherefore the Plattner method is suggested as preferable.

O. S. E.

WAVERLEY GOLD DISTRICT, NOVA SCOTIA.

Notes on some Special Features in Lode Formation and Deposition of Gold, as presented in the Waverley Gold District, Halifax Co., Nova Scotia. By B. C. WILSON. *Mining Society of Nova Scotia, Transactions, vol. ii., pages* 32-46.

The so-called auriferous veins of Nova Scotia are interbedded with slates and other rocks. Those at Waverley occur on an anticlinal running from east to west, broken near the middle by a north-and-south fault, which occasions doubt as to whether the veins on either side are identical. The anticlinal is most pronounced in the western division, the veins as you go westward becoming flatter; while at the extreme west exposure the vein may be seen to turn completely—one side dipping to the north and the other to the south.

The ore is free-milling, with a limited quantity of sulphides. The gold is usually fine, but occasionally extremely rich patches are met with. The sulphides are mainly arsenical pyrites, which, when embedded in the body of the quartz, is said to be usually rich in gold, but the reverse when it occurs on the walls.

The workings in the western division have reached a depth of nearly 400 feet. There is little or no underground water in the district, such water as is met with having come in from the surface.

In the eastern division, the vein, both at the surface and in depth, is "crimped" or folded upon itself, so that what would, if smoothed out, be a vein of 10 to 12 inches wide, folded together in this way, fills a space of 20 to 30 inches, and with the associated slate occupies a belt of 45 inches between the upper and lower walls of hard metamorphic rock. Where the surface-outcrop was laid bare, the vein looked like a layer of barrels, and hence received the name of "barrel lode."

That the vein was plastic subsequently to its formation is indicated by the fact that in some instances the quartz is found forced into wedge-shaped cavities in the walls, but so that its edges remain rounded, and a small angular space is left at the extremity of the crack, much as would be the case if putty were pressed into a similar cavity. G. E. C.

THE MINERAL RESOURCES OF SOUTH-EASTERN ALASKA.

By G. W. GARSIDE. *American Institute of Mining Engineers*, 1893, *vol. xxi., pages* 815-823, *and map.*

The chief metalliferous belt follows the mainland shore in a north-west and south-easterly direction for more than 100 miles.

Gold is found in the free state, and is largely worked by hydraulic mining. The veins carry gold associated with sulphides of iron, lead, etc., with silver and lead ores, and with small quantities of copper, zinc, and iron ores. The most important district is the Gold Creek, where the well-known Treadwell mine is situated, on the east side of Douglas Island. A. W. G.

CRIPPLE CREEK GOLD-FIELD, COLORADO, U.S.A.

Notes on the Geology of the Gold-fields of Cripple Creek, Colorado. By H. L. MCCARN. *Science (New York), vol. xxiii., pages* 31-35.

The Cripple Creek district is surrounded by granitic gneisses, altered towards the centre into a complex variety of schists, aplites, felstones, conglomerates, etc., all formed by metamorphism from the normal "granite," and all shading off into one another. Of these the best marked types are :—

1.—A grey felstone of leached-out appearance, often coloured yellowish, or brownish by iron oxides, finely granular, frequently containing small grains of pyrites. This, the porphyry of the miners, encloses many of the best mines.

2.—Mica-schist, of which there are two varieties. In one the mica is black and iron-bearing, the rock being friable; the other is a tough laminated rock with silvery-white muscovite. Good veins often occur at the contact between this and other rocks.

3.—Hornblendic felstones, mostly dark in colour, often very hard and compact. Evidence of bedding is sometimes visible, but stratigraphical study is difficult owing to the wash formed by atmospheric denudation, which covers the rocks sometimes to depth of 80 feet.

The veins are unquestionably true fissures, as indicated by their crossing the bedding, the phenomena of slickensides, etc., and the gold occurs as usual in more or less vertical shoots. The country-rock is often fissured for some distance parallel to the veins, such quartz-filled cracks often yielding the richest stone. The clay-selvages also are often rich. The country-rock is often mineralized for considerable distances, so that the width of the vein cannot be measured.

Much of the ore is coated and impregnated with fine white auriferous pyrites, associated with sylvanite. Very few other valuable minerals are met with in the district. Limonite occurs as a veinstone, and also occasionally as the capping of the lodes.

Most of the veinstone is merely kaolinized "country." Variously coloured jasper occurs as a veinstone in some cases, the bright-coloured cryptocrystalline portions being reputed rich in gold. The author thinks that the gold was derived from the iron-bearing mica of the surrounding "granite," either directly or from pyrites derived from this.

Only two eruptive masses are known, neither of which has influenced the lode-mineralization. The more important is a dyke about 30 feet wide, dark grey to black in colour, showing minute grains of felspar in a matrix of amphibole or pyroxene. At one point a sheet of quartz is found between this and the granite, which is impregnated with copper minerals, evidently derived from the dyke. This is the only occurrence of copper in the district.

Most of the decomposed "wash," before referred to, is auriferous, and might be profitably hydraulicked if water were available. The absence of evidence of glacial or stream action accounts for the thickness of this wash, the valleys being synclinal troughs rather than valleys of erosion. G. E. C.

THE MOTHER LODE OF CALIFORNIA, U.S.A.

The Mayflower Mine, California. ANON. *Engineering and Mining Journal (New York)*, 1894, *vol. lvii., pages* 173-174.

The mother lode is a band of graphitic slate, seamed with quartz-veins, and bordered by walls of greenstone, forming part of a belt of slates and eruptive rocks, which runs north and south parallel to the Sierra Nevada for over 100 miles, with an easterly dip. Owing to its greater hardness as compared with the enclosing rocks, its outcrop stands up in conspicuous masses. The quartz bodies occupy irregular fissures in the slate and greenstone, sometimes crossing both dip and strike, but generally conformable They are thus classed :—

1.—Hanging-wall veins mainly on the contact between the slate and the eastern greenstone wall.

2.—Foot-wall veins irregular and of limited extension.

3.—Counter veins, of little importance excepting as indicators.

4.—Greenstone veins, quartz-filled fissures in the greenstone walls.

Recent experience on the mother lode indicates the existence of two separate ore-bearing horizons. The first extends from the surface to a depth of 600 or 700 feet; this is followed by a barren zone, and subsequently another rich zone extending from about 1,100 feet to the lowest depths yet reached. G. E. C.

IRON ORES IN THE FRENCH PYRENEES.

Note sur les Richesses minérales des Pyrénées orientales. By CHARLES HELSON. *Annales de la Société Géologique du Nord,* 1893, *vol. xxi., pages* 159-169.

After being more or less extensively worked for many centuries, the mines in the French Pyrenees were abandoned at the time of the Revolution of 1789, and only within very recent years have operations been restarted in some localities. Two of the main factors which apparently determined this long abandonment, namely, the want of sufficient mechanical power and the want of cheap and rapid means of transport, can be now easily eliminated.

The metalliferous deposits of the Department of the Eastern Pyrenees are grouped around the base of the Canigou: in the west, especially in the neighbourhood of Prades, and in the east in the districts of Batère, Ballestavy, and Velmanya. There are 27 concessions for iron-ore mining in the Department, occupying a total area of about 25,000 acres. By far the most extensive, and the only claim actively worked, is that of Fillols, supplying ironworks in the south of France. Capital is the one thing needful to develop the others.

The ferruginous deposits are in the form of veins, layers, and pockets in saccharoidal limestones, and in clay-slates resting on the older granites. Near Prades, they strike east-and-west along a line more than 12 miles in length: the average thickness of this ferruginous band is 65 feet, but in the Batère-Velmanya group it increases to double that measurement. The ores are exceptionally rich: they consist chiefly of magnetite, hæmatite, and decomposed iron carbonate, all of which are manganiferous. Tables of analyses of the Constantine (Algeria), Bilbao, and French Pyrenean iron ores are given, showing that the last-named suffer no disadvantage in the comparison. Thus at Velmanya the percentage of metallic iron in the ore is 64·5, at La Pinouse it is 60 and 62, according to determinations made in the Paris School of Mines.

Various authorities are quoted in support of the view that a brilliant future awaits this comparatively neglected mining field, and the author is sanguine enough to think that France can supply herself with iron ores from the Pyrenees to the complete exclusion of foreign imports of ore. He states that the new railway rates will allow of the Pyrenean ores being put down at St. Etienne, Creusot, Alais, etc., at prices defying any possible competition, and Port Vendre being only 50 miles away, the ores could be sent by sea to the Northern French and Belgian ironworks. O. S. E.

THE HÆMATITES OF NASSAU, GERMANY.

Das Vorkommen der devonischen Eisen-und Manganerze in Nassau. By WILHELM RIEMANN. *Zeitschrift für praktische Geologie,* 1894, *pages* 50-57, *with figures in the text.*

The iron and manganese ores of Nassau occur in the Devonian formation of the districts of Wiesbaden and Wetzlar. The rocks form a great complex of squeezed, uptilted, and overthrust quartzites, grauwackes, slates, and limestones, cut through here and there by diabases, porphyries, and basalts. The general strike is south-west and north-east, the dip south-easterly.

From the miner's point of view the highly fossiliferous Stringocephalus-limestone (Middle Devonian) is of importance, because of the manganiferous brown iron ores associated with it. It is in part massive, and is then largely burnt for cement, in

part weathered, "ragged," and dolomitized. In some places the limestone is so highly impregnated with iron oxide that it makes an excellent flux for the blast-furnace.

The Upper Devonian Goniatite-limestones make good building-material, and often become very ferruginous where they form the hanging-wall of the red hæmatite-deposits. The schalsteins or greenstones are the constant associates of these deposits, particularly in the Lahn basin.

Considering, first of all, the brown iron ores, these may be classified as follows:—

(*a*) Those filling up fissures in the rock, or inequalities in the very irregular surface of the Stringocephalus-limestone, where that surface does not come to day. The ores are manganiferous and occur especially where the limestone passes into dolomite, or has become entirely dolomitized. They are generally separated from immediate contact with the limestone by a thin layer of clay. In the Ebersgöns and Oberkleen mines the limestone "footwall" is nowhere dolomitized, the "hanging-wall" is Devonian slate, and the deposits may be regarded as true contact-formations. Manganese ores are of rarer occurrence.

(*b*) Those occurring in decomposed greenstones. The ores are found in reniform masses, in nests, in pockets, and in layers of inconsiderable extent. They are highly siliceous, and, containing only 30 to 35 per cent. of iron, are of small industrial value.

(*c*) Those deposits overlying the Upper Devonian, where, besides the forms mentioned in the previous group, they are found also as veins.

So much for the brown hæmatites; the red are of more importance in the area under review. In some rare cases they cut through the strata as "veins," but, as a rule, they are regularly interstratified with other beds, and are, from the point of view of position, of an origin contemporaneous with that of the "country rock" (mostly Upper Devonian). It is possible, however, that they were originally limestones which, by taking up iron oxide, have gradually passed into hæmatite. They are very irregular in thickness, in some places attaining 65 feet, at others thinning away to nothing, and they generally occur along the boundary between two different rock-facies. Where the deposits are valuable, the "country rock" is, as a rule, much weathered. In some of the Lahn Basin mines the ironstone becomes more calcareous the deeper it is worked, and passes into limestone-beds. In others it becomes highly siliceous, but it would be a mistake to generalize from these observations, and the author does not subscribe to the opinion that below the level of the valley-bottoms the deposits on the whole become unworkable. He adduces many examples to the contrary; at the Raab mines, to take one instance, the ores at 393 feet below the adit-level are richer than those struck at that level. The red hæmatites contain generally 40 to 50 per cent. of iron, but cases are known where they contain as much as 69 per cent.

In addition to the deposits previously described there are the so-called "rolled deposits." They consist of ironstone-gravels lying at or near the surface, often on the slopes of such hills as have at a higher level outcrops of hæmatite-deposits proper. It is clear that these gravels are derived from the aforesaid deposits, and are a recent alluvial or drift-formation. They are worked chiefly at Oberndorf, and the hæmatite from them contains on an average 56 to 59 per cent. of iron. They are practically free from phosphorus, and are therefore specially adapted to the Bessemer process. Magnetite, spathose, and specular iron ores are in places associated with the hæmatites.

The number of mines at work is 216, employing in round numbers 6,000 work-people, and producing annually between 750,000 and 800,000 tons of iron ore and 15,000 tons of manganese ore. O. S. E.

THE MESABI IRON-RANGE, MINNESOTA, U.S.A.

By H. V. WINCHELL. *Transactions of the American Institute of Mining Engineers, vol. xxi., pages* 644-686.

The Mesabi iron range extends for 140 miles from the Canadian boundary in Minnesota to beyond the Mississippi river.

The width of the ore-belt varies from 1 to 2 miles. The ore lies in nearly flat beds, varying in thickness up to 100 feet. To the eastward it is hard, black, and magnetic, due probably to the heat of the gabbro which has flowed over it, while in the centre and west it contains soft and hard hæmatite, limonite, and goethite.

The ore is deposited in regular beds, constituting part of the Taconic strata, and not in veins with hanging- and foot-walls as is popularly supposed.

The writer concludes by giving a number of analyses of the ores, describing mines already opened, and the method and cost of mining. A. W. G.

THE MAGNETIC IRON-ORES OF ASHE COUNTY, NORTH CAROLINA, U.S.A.

By H. B. C. NITZE. *Transactions of the American Institute of Mining Engineers, vol. xxi., pages* 260-280.

Ashe County is in the extreme north-west of North Carolina, and the ore-deposits are situated in the area of crystalline rocks consisting of gneiss, and hornblende and mica-schists.

The district is practically undeveloped, and covers an area of about 150 square miles. The ores are principally magnetites, suitable for the manufacture of Bessemer pig-iron, brown hæmatites and specular ore being also found. The structure of the magnetite-beds is undoubtedly lenticular.

The district is divided into three main belts. The Ballou or river belt, the Redhill or Poison branch belt, and the Titaniferous belt, the last of the three being apparently the most important. Generally, the ores are of good quality, low in sulphur, and below the Bessemer limit in phosphorus. Though containing much silica, high-grade products could easily be obtained by magnetic concentration.

A. W. G.

THE ZINC AND LEAD MINING DISTRICT OF RUBLAND (CARINTHIA).

Die Zink-und Bleierzbergbaue bei Rubland in Unter-Kärnten. By R. ROSENLECHER. *Zeitschrift für praktische Geologie,* 1894, *pages* 80-88, *with map in the text.*

Limestones and clay-slates are the predominant rocks of the area. The limestones are generally of an uniform colour, varying from light silver-grey to deep iron-grey, the darker ores containing small carbonaceous particles of a dense black hue, and emitting a fœtid odour when struck. There are some thin beds of a black seamed limestone, similar to that associated with the galena and calamine-deposits of Raibl. The limestones are, in many localities, traversed by innumerable veins of calcite, which are somewhat optimistically regarded by the miners as forerunners of ore-deposits. The general dip is 40 to 45 degs. north towards the Drave valley; the limestones probably belong to the lower division of the Upper Trias.

The clay-slates or shales are strongly bituminous, and abound in pyritous concretions: they are of a very dark-grey colour, almost carbonaceous in aspect. In some few cases they pass gradually into the limestones, but, as a rule, they are sharply marked off from these by a thin, soft, decomposed clayey layer. They are very irregular in thickness, in dip, and in strike, and are much fissured.

Of less importance are the deep red, strongly ferruginous, flaggy sandstones, which occur in the northern part of the district.

In the above-described complex of limestones and shales lie the ore-deposits, their mode of occurrence being so irregular as to give few clues from which the prospector may safely generalize. There are, however, good grounds for believing that they were formed by the circulation of fluids, holding the ores in solution, along the system of fissure- and joint-lines in the limestones, but near the contact with the shales. Tectonic considerations show that the whole complex was thrust up by contraction of the earth's crust, and the difference of elasticity between the limestones and the shales must have induced great fissuring of the former rocks, particularly near the contact with the latter.

Mining has lately been for the third time resumed in the district, the zinc ores being the most prized, whereas under the old conditions the lead ores alone were worked, the zinc ores being left in place or tipped on to the wasteheap. The thickness of the ore-deposits does not usually exceed (0·50 to 0·75 metre) 1·64 to 2½ feet, but in some cases it becomes as much as (2 metres) 6·56 feet.

The minerals composing the ore-deposits are the zinc-blendes, of a clear honey yellow to a light greyish yellow colour, galena, heavy spar, pyrites, anhydrite, in separate crystals or fissure-surfaces and in hollow cavities, and quartz in a state of microscopically fine division. According as one mineral or the other is predominant, the miner strikes plumbiferous blende-deposits or blende-bearing galena-deposits. True calamine has not thus far been found in the Rubland district, but the term "calamine" is locally applied to hollow masses of blende which yield on hammering a nucleus of good zinc-blende, and are merely weathered a little externally.

At the first glance the ore-deposits appear to be scattered haphazard over the district, but on looking at the author's sketch-map one is enabled to distinguish three separate "tracts" or lines of deposits ranging practically parallel to the southern mountain-chain (¼ and ½ mile apart respectively), and crossing the district almost due east and west.

Mining operations in this area are attended with great difficulties, and with considerable risk to those who undertake them. A good deal of capital needs embarking in the enterprise to secure satisfactory results. The methods of working afford no striking particularity, but it is worth while noting that the ores are washed in the Koflach Graben by means of plant driven by turbines, the installation permitting of 60 tons of "small" to be passed through the washing apparatus every twenty-four hours. The washed ores are taken 4½ miles by a steep waggon-road to the nearest railway-station. O. S. E.

IRON GLANCE AND MAGNETITE ARTIFICIALLY PRODUCED FROM THE IRON RESIDUES FROM ANILINE WORKS.

Künstliche Bildung von Eisenglanz und Magnetit in den Eisen-rückständen der Anilinfabrikation. By DR. WILHELM MÜLLER. *Zeitschrift der Deutschen geologischen Gesellschaft*, 1893, *vol. xlv., pages* 63-68.

For some little time past the residues from aniline factories have been worked up in the Phœnix blast-furnaces at Laar, Ruhrort. Premising that the necessary hydrogen for obtaining aniline from nitrobenzol is produced by the reaction of hydrochloric or even acetic acid upon metallic iron, the author states that the ferruginous mud, which remains after the aniline has been distilled off, is allowed to settle on draining-floors, and when it has assumed a more pasty consistency it is taken away to the ironworks where it is shovelled out into heaps which lie in the open.

Under the influence of atmospheric air very active oxidation is set up in these heaps, and goes on to such an extent that they frequently become incandescent. Indeed, it is stated on the authority of Mr. C. Reinhardt, the superintending analyst of the ironworks, that some of the barges carrying these residues have been known to take fire—probably from the same cause. The process of oxidation is accelerated by the organic substances present among the residues. It implies, of course, considerable chemical change—a change emphasized by a remarkable transformation in the physical characteristics of the mass. The colour changes from blackish-brown to red, the stuff hardens so that it has to be broken up with pickaxes to be got into the furnace, the organic substances originally present disappear, and those parts of the mass which have been most heated have assumed a perfectly metallic aspect, brilliant lustre, and steel-grey colour. In these are numerous hollows lined with well-shaped crystals. Careful examination proves these to be intergrowths of magnetite with iron glance. In nature, such intergrowths are known in the fumaroles of Vesuvius. O. S. E.

MANGANESE IN THE CAUCASUS.

Engineering and Mining Journal (New York), 1892, *vol. liv., page* 28.

About 26 miles from the station of Kvirily, on the Transcaucasian railway, manganese ore was discovered some years ago in very large quantities and of a superior quality.

The quantities of ore are stated to be very large, as the surface of the manganiferous lands is said to be no less than 84 square miles. The ground belongs to a great many proprietors, mostly peasants, and the extraction of the ore is carried on in a primitive way. The cost of mining varies from 2s. 6d. to 4s. per ton; the proprietors are paid about 2s. 6d. per ton; the carriage from the mountains and to the railway station varies from 24s. to 32s. per ton, and the railway carriage from Kvirily to Poti amounts to 8s. per ton. The price of the manganese ore on board ship at Poti (Black Sea) is about 36s. to £2 per ton. J. W.

MARBLE QUARRYING.

By G. W. PERRY, Ph.D. *Engineering and Mining Journal (New York)*, 1892, *vol. liii., page* 207.

The invention of the diamond drill and the channelling-machine changed all methods of marble quarrying. As marble lies in a solid mass and breaks irregularly and with difficulty, it cannot be split or rifted out like some other kinds of stone. Therefore it is necessary to cut almost or entirely around a block, a long and tedious process by hand drills. When a quarry was worked by hand, one with a slight dip was valuable, as deep openings could not be made; but now, the greater the dip the more valuable, because the sooner sound stock will be found. Then the blocks were very small, just large enough for the tombstones of those days, and they must, therefore, conform to the grain of the stone. Now they range from 5 to 20 tons in weight, while, for special purposes, much larger blocks are taken out. Then the stratification was followed of necessity after the unsound material near the surface was blasted off. In the Sheldon quarry, Vermont, the old hand workings may be seen on the right, showing the dip to be about 60 degs. As before said, the stone lies in one solid mass, the lines simply showing the cutting of the blocks. It has been found by experience that it is not best to blast off even the unsound stock lying near the surface, as the shock is likely to shatter the stone for some distance below, and if the effect does not show at once, cracks are apt to appear upon exposure to the weather. The machines are put at work upon the top of the deposit, and the unsound blocks are patiently taken out and thrown into the dump heap.

The opening made is not very large, as the marble is sounder and more valuable at a depth. By means of the machines it is possible to cut under the side walls, thus making the floor of the quarry much larger than the top, great columns and buttresses being left as supports.

The channelling-machine is like a little locomotive, running upon a narrow-gauge steel track. As it travels it strikes on one or both sides of itself with a set of five drills set at different angles. Thus going back and forth upon the floor of the quarry it cuts a channel about 1¼ inches wide to a depth of 6 feet. A double machine will cut as much as fifty men. There is thus cut a long block still fast on its bed and at the ends. The machine is now turned around and the long strip cut into blocks about 8 feet long, which are now free, except at their beds. One of these must be partially sacrificed in order to make a working-place from which the others may be operated upon. A hole is drilled in the centre of one of them to a depth a little below the channel, and a small blast of powder then will easily lift it. In the opening thus made a diamond drill is placed, and holes are drilled about half through the blocks under their beds, when they can be easily wedged off. When once the first has been taken out, then all the others on that floor can be broken into blocks by the diamond drill or the gadder, these being broken along the lines of stratification, instead of at right angles with the surface. J. W.

THE QUICKSILVER MINES OF TUSCANY.

Die Quecksilbergruben Toscanas. By R. ROSENLECHER. *Zeitschrift für praktische Geologie*, 1894, *pages* 337-353, *and plates IV.-V.*

The central point of the Tuscan quicksilver mining district is the volcanic peak of Monte Amiata (5,687 feet high), which is the result of an eruption in Oligocene times. The trachytes cover an area of 25,000 acres, and their outflow was doubtless the determining cause of the fissures in the neighbouring rocks which were subsequently filled with metalliferous ores. Eastward rise the Nummulitic Limestone crags of the Monti Civitella, La Penna, and Nebbiaio; southward and westward, ever diminishing in height the farther south one goes, range the undulating ridges of Middle and Upper Eocene limestones. Miocene sands, with sometimes a calcareous sometimes a ferruginous cement, crop out near Pian Castagnaio and form the summit of Monte Buono; they are, so far, barren of fossils. Patches of Pliocene, consisting of a calcareous shell-breccia, are scattered here and there over the district.

The chief line of fissure strikes north and south, and is crossed nearly at right angles by another series of fissures. The most abundant and richest metalliferous deposits are at the points of intersection of the two systems; farther away from the main fissure-line the deposits get sparser and poorer.

In the Monte Amiata trachyte in small pocket-shaped cavities are deposits of bole and yellow and brown ochres, particularly near the contact with the limestones. Numerous springs gush out from the trachyte, and in the height of summer the rich vegetation on this rock presents a striking contrast with the sun-scorched, burnt-up district to the southward.

Serpentines of Eocene age occur at various points, and at the contact with the stratified rocks some small finds of cinnabar have been made. Below the oldest Eocene strata come Globigerina-limestones of Senonian age, followed in descending order by shales, strongly manganiferous, and containing flint in bands and nodules. These are underlain by a much fissured limestone with masses and bands of flint in its lower portion, and having many large and irregular cavities. The cavities at Cornacchino, to take one instance, will be alluded to further on. This limestone is

on an average 65 feet thick; below it is a great flinty formation 130 feet thick, full of clefts and cracks which contain cinnabar—sometimes these clefts widen out into small chambers filled with clay impregnated with cinnabar. This impregnation extends also to the limestone which comes below the flint, and is possibly of Jurassic age.

Besides occurring in the trachyte near Abbadia San Salvatore, cinnabar is found in all five of the stratified formations of the district, in the Pliocene, Miocene, Eocene, Neocomian, and Jurassic. Diverse as the character of the deposits may be, their common origin from solfataric springs which held in solution cinnabar and other sulphides is evident, and they may be all ranged in the one category of "impregnation-deposits." The hydrogen-sulphide springs and gas-wells which still abound in the district lend confirmation to this view.

Among the most characteristic occurrences of the quicksilver ores are those at Siele, Solforate, Cornacchino, Montebuono, and Abbadia San Salvatore.

The Siele mine belongs to a Leghorn firm, and is one of the most considerable in the district. Here, in Middle Eocene limestones and shales, forming a complex about 165 feet thick, are flattened "pockets" filled with a dark grey clay, veined with calcite, and termed by the Tuscan miners *biocca*. In this are embedded iron pyrites and cinnabar, more or less concentrated at one point, or sometimes evenly dispersed throughout the mass. The richest deposits contain ores yielding as much as 60 per cent. of metallic mercury; in such cases the red colour peculiar to cinnabar permeates the clay. Other ores occur, in a state of very fine division, containing 10 to 15 per cent. of metallic mercury, but, as the daily and monthly statistics of the mines show, the true general average is 5 to 6 per cent. The best part of a "pocket" is generally near its lower end, where it contracts funnelwise into a narrow tube, through which, probably, the inflow of the metalliferous solutions took place. The average longitudinal extent of the "pockets" is from 160 to 260 feet, vertical from 130 to 160, and thickness $3\frac{1}{4}$ to $6\frac{1}{2}$ feet.

A long adit, not very many feet above the level of the Siele stream, led in former days to shallow shafts, mostly provided with steps, but within the last few years two vertical shafts have been put down, one of which (174 feet) is used as a reserve and pumping shaft, the other (820 feet) for haulage and drainage. The last-named shaft is elliptical in cross-section (area 10·17 by 8·85 feet), and is almost entirely lined with blocks of trachyte. The haulage engine is a single-cylinder condenser of 40 horse-power: the ores are taken direct from the pit-mouth, along a small incline a couple of hundred yards in length to the roasting-ovens.

The geological conditions obtaining at Solforate are very similar to those above described at Siele, but the appliances at the former mine are primitive and the method of working incredibly negligent: a great drawback also at Solforate is the want of water.

At Cornacchino we come to the second most important mine in the district of Monte Amiata, opened only in the year 1879. Here the cinnabar occurs at three distinct geological horizons, whose outcrops may be easily followed above bank, namely, the Lower Neocomian Limestone, the Cretaceous flint-rock, and the Jurassic Limestones below these.

In the flint-rock the narrow clefts are full of a sandy loam impregnated with cinnabar, which is extraordinarily free from pyrites. But mining did not pay here until the hanging-wall of Neocomian Limestone by chance revealed in it the presence of cinnabar-deposits. These are of very irregular form, and are richer in the marly than in the tough compact limestones. In the former, the cavities filled with cinnabar-clay or "nests" seldom measure more than 8 to 10 feet vertical and 5 to $6\frac{1}{2}$ feet horizontal. The "nests" are connected one with the other by very small

cracks ("canals"), which acted as so many pipes for the passage of the mineral solutions. In the tough limestones the ores occur as lodes of insignificant thickness. In the highly-decomposed limestones much of the calcareous matter has been leached out, swept away, and replaced by masses of grey and yellow pyritiferous clay impregnated with cinnabar. These masses sometimes measure 3,000 or 4,000 cubic feet, sometimes less than 100. The distribution of the ore, too, is irregular, and the average percentage of metal is 1 to 1·5. In accordance with the hypothesis that the metalliferous solutions came from below, the most recent exploring operations have revealed the presence of cinnabar-deposits in highly decomposed Jurassic limestones beneath the flint-rock.

The workings at the Cornacchino mine were formerly conducted in the most unmethodical fashion. Rich and easily attainable deposits were worked out, just as they happened to be found, while poorer deposits were passed over, with the result that the production was extremely fluctuating, and finally sank to *nil*. But in recent years, with the advice of the author, working was re-started on a systematic plan, and so far with the best results. Drainage need not be considered in a mine where the impermeable shales which form the roof keep the workings practically watertight.

From the upper horizons the ore is slid down shutes or small vertical shafts, known as *caminetti*, to the floor of the main level, where it is loaded into tubs and hauled up to bank. Ores in the flint-rock have of late been scarcely worked at all, and, as above-mentioned, the average percentage of metal in those that have been worked is 1 to 1·5.

They are therefore dressed for smelting by a very simple buddling process, the product of which is a mass usually containing 15 to 30 per cent. of metallic mercury, and this is dry-distilled in two retort-furnaces; poorer stuff is simply calcined in a blast-furnace fired with charcoal. The maximum production ever known at this mine is 400 to 500 bottles of mercury per month (each bottle containing 76 lbs.), the number of workpeople averaging 100 to 120.

The Montebuono mine, on the northern side of the mountain of the same name, is the southernmost of the quicksilver mines that are now worked. Here the Miocene sands overlie and conceal the Nummulitic Limestone. When the workings were driven down about 100 feet through the sands, a great vertical crevice, 6 feet or so wide, was struck. It appears to split the whole mountain, and is no doubt one of the results of the ancient volcanic outbursts of Monte Amiata. This crevice is filled up with Miocene sands and clays impregnated with cinnabar in an extremely fine state of division, and in the immediately neighbouring rock are several funnel-shaped cavities also filled with metalliferous sands and clays, the proportion of cinnabar increasing with the depth from the surface. On the whole the average percentage [of metal] is 0·4 to 0·5.

The workings comprise three levels, the highest of which is already worked out, the lowest is in forewinning, and the middle one is in active working. The vertical distance from the deepest to the middle level is 121 feet, and from the middle to the highest 98 feet. The ore is slid down a small shaft to the floor of the lower level, and loaded into tubs which run along rails to the smelting-works. On account of the state of fine division of the cinnabar, the attempt to enrich the ore-stuff by buddling as at Cornacchino proved ruinous, and the stuff is smelted direct as got from the mine in a Czermak calcining-furnace, with movable bars and an iron condenser. Eighteen to twenty metric tons are dealt with every twenty-four hours, and the fuel is beech and oak-logs (daily consumption, 247 to 282 cubic feet). The number of workpeople at this mine is sixty to seventy, the daily production averages 66 to 88 lbs. of mercury, and as the cost of working has to be distributed

over this quantity, the profits are small. But there is good hope of striking some richer and better paying deposits in the mine, as the workings are carried deeper down.

At Abbadia San Salvatore, the northernmost point of the quicksilver district, the trachytes form a kind of bay cutting into the mountain-massif proper. In this bay lie along an east-and-west line several points where ore has been found, and the prolongation of the line leads direct up to the summit of Monte Amiata. This leads to the inference that we have here a radial fissure through which the metalliferous solutions found their way upward. Some workings have been started in the trachyte, but have not been carried further than the experimental stage. The rock is decomposed almost to a sand, and appears at the first glance extremely rich in cinnabar, but, despite its fine colour, the metallic content is less than 0·1 per cent. Moreover, water comes in with such force that powerful pumping-engines are needed to deal with it, and really cheap fuel is not to be had for firing them.

At the contact of the limestone and trachyte, however, a loamy band about 20 inches thick contains masses of pure cinnabar several pounds in weight, and a great many less pure reniform and lenticular nodules of the ore. In view of this promising outlook the winning was actively pushed forward, despite a considerable inflow of water, but soon the workings were overwhelmed by great masses of quicksand and loam, and were perforce abandoned. The miners are driving a gallery through the trachyte, so as to get round this bad place, and intend to strike the contact-rock nearer the mountain-summit. Similarly, the forewinning in the Eocene Limestones themselves promised excellent results, but was interrupted by the invasion of quicksand, and there the workings had to be given up entirely.

Besides the localities to which particular attention has been drawn, exploration and forewinning operations have been tried at several other points in the district, but they have resulted mostly in failure. Insufficient capital and want of perseverance and technical knowledge partly account for this, and partly also the insuperable obstacles which the Tuscan landowner often puts in the way of the miner, for the old law that the minerals belong to the owner of the soil still prevails.

Quicksilver mining in the Monte Amiata district is, comparatively speaking, an industry of quite modern growth. The conditions of wages and labour are favourable to enterprise, and difficulties of transport have vanished. There are excellent roads and new railways in the district. Wood fuel from the forests stretching away towards the Maremme is still to be got in abundance. For all of which reasons the author is hopeful as regards the future development of the industry. O. S. E.

NOTES ON THE WHITE MICA DEPOSITS AND MINES OF THE SAGUENAY REGION, CANADA.

By J. OBALSKI. *Canadian Mining and Mechanical Review*, 1894, *vol. xiii., page* 7.

The first working in the Saguenay region dates back only to the end of 1892. The country rock is mainly felspathic and dioritic gneiss of Lower Laurentian age, frequently covered by trap-dykes.

The mica occurs in veins of coarse granite, generally bearing about north-east. Of these fifteen were noted; but in many cases the mica-crystals were too small, or the veins too narrow, for profitable working. It is always white (muscovite), brownish when in thick crystals, as distinguished from the green crystals of the Ottawa region. It is clear, free from spots, elastic, and possesses good cleavage. In two cases only, the McGie and Beaver Lake mines, has work been done as yet on any considerable scale, both of these being in the Bergeronnes township. As the workings are situated about 12 miles from the St. Lawrence, the cost of transport will not be excessive. G. E. C.

TRADES UNIONS.

Rapport sur les Syndicats professionnels. Bulletin de l'Union des Charbonnages, etc., de la Province de Liége, 1892, *pages* 138-150.

In France, trades unions are regulated by the law of March 21st, 1884. The legislature of 1791 found that unions, formed at first to resist the feudal oppressions, were becoming in their turn sources of danger to the efficiency of industry and the freedom of the subject. They, therefore, at that time suppressed the right of association among the industrial classes.

The law of 1884 was framed to repeal the penalties imposed by the laws of 1791, and was meant to give complete liberty of association. By this law either workmen or employers may continue together for their own purposes, but it still remains a penal offence to attempt to raise or lower wages or to interfere with the liberty of trade or work by means of violence, riot, threats, or fraudulent manœuvres. By this Act the law of France is made the same as it has been for a long time in Belgium, with one exception, viz., the Belgian law considers moral coercion in the same light as physical violence, and punishes those who attempt to enforce any proscription or fine, either against workmen or employers.

Several restrictions are imposed upon the unions in France as to the property they may hold, and the registration of their offices and directors. Unions are at liberty to combine together for the purposes of education, or the defence of their interests. Proposals are being made to amend the French laws so as to permit unions of masters and workmen to combine together for charitable purposes. Those proposals, however, have always been defeated by the fear that they might be used for the propaganda of the Roman Catholic religion. An account is also given of the laws regulating the trades unions in Great Britain.

In Germany, the unions are regulated by the laws of 1881 and 1884, and these laws are found to work satisfactorily. One provision is that an employer cannot have apprentices unless he be a member of the corporation of his trade. These corporations are formed into groups, said to resemble trades unions, one of the most important being the Union Hirsch.

In Belgium, the associations are regulated by the common law, but since 1889 the Chamber of Representatives has been engaged with a proposed law conferring on the unions the benefit of *personnification civile*. The object of the bill is to permit unions to receive donations and legacies, and the unions would also have the same rights with regard to real property as are enjoyed by private citizens. This law has not yet been passed, but an interesting account is given of the various arguments for and against the project. R. W. D.

UTILIZATION OF ZINC FUMES.

Verfahren zur Verwerthung des bei den Zinkblende-Röstofen fallenden Flugstaubes. By G. KRAUSE. *Zeitschrift für das Berg-, Hütten- und Salinen-Wesen im Preussischen Staate*, 1891, *vol. xxxix., page* 152.

The zinc which is present in the fumes as a sulphate (10 to 21 per cent.) and the iron (as ferrous sulphate, 2 to 3 per cent.) are washed out of it and precipitated by an alkaline carbonate. In this way an artificial calamine, containing from 45 to 50 per cent. of zinc, is produced and calcined into a stiff mass, which is then subjected to the ordinary processes of zinc manufacture.

In one sample tested the sodium sulphate obtained as a by-product was of sufficient value in itself to cover the cost of extraction of the zinc and iron from the fume. Great economy is also effected by precipitating with barium nitrate the solution of sulphates obtained in washing the fume, and then washing the filtrate and precipitating with sodium carbonate as before, the products of the whole process being calamine, barium sulphate, and sodium nitrate. O. S. E.

II.—REPORT OF THE CORRESPONDING SOCIETIES COMMITTEE OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 1894.*

The Corresponding Societies Committee of the British Association beg leave to submit to the General Committee the following Report of the proceedings of the Conferences held at Nottingham and at Oxford.

NOTTINGHAM.

The meetings of the Conference were held on Thursday, September 14th, and on Tuesday, September 19th, in University College, Nottingham, at 3·30 p.m.

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At the first Conference (September 14th, 1893) the Corresponding Societies Committee were represented by Dr. Garson (in the chair), Mr. Topley, Mr. Symons, and Mr. T. V. Holmes (Secretary).

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SECTION C.

Mr. A. S. Reid said that the Geological Photographs Committee of the British Association were publishing their fourth Report this year. During the year they had received more than forty new photographs, making the total collection 846; they were all British. Their appeal to the Corresponding Societies had been more successful than in any previous year, but there was still much to be done, and he hoped the delegates would stir up their societies on this point. As to the best camera, the most portable was to be preferred. He had also to report that many prints had been sent in without the name of the societies sending them, that of the photographer, or that of the place photographed. They had decided not to lend any more photographs to the societies, unless such photographs were sent in duplicate. Mr. Jeffs, the Secretary of the Geological Photographs Committee, had unfortunately been ill during nearly the whole of the year, and this had seriously hampered their work.

Mr. Tate said that, with reference to geological photographs, many of those sent in were probably of little value. He trusted that some day the Geological Photographs Committee would be able to select typical examples and place them where they would be of use to the Corresponding Societies. Some had been sent from Belfast, the district he represented.

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SECTION E.

Mr. Sowerbutts remarked that their member, Mr. Crook, went before the departmental committee appointed to consider the state of the Ordnance Survey in order to give evidence.

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SECTION G.

Professor Merivale had nothing to report about Flameless Explosives.

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At the second Conference, (September 19th, 1893) the Corresponding Societies Committee were represented by Dr. Garson (in the chair), Mr. F. Galton, Mr. Symons, and Mr. T. V. Holmes (Secretary).

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SECTION A.

Mr. Symons said that the work of the Earth-tremors Committee was going on under the care of Mr. Davison, and he did not think that there were other committees connected with Section A that bore upon the work of the delegates. With regard to the Report of the Earth-tremors Committee, he should like to hold it in suspense for a while, in the hope of future co-operation with some of the Corresponding Societies.

Mr. M. H. Mills thought that earth-tremors was one of the subjects in which members of The Federated Institution of Mining Engineers could assist.

Mr. Symons enquired if it would be possible to place instruments underground at a depth of 100 feet?

Mr. Mills did not think there would be any difficulty.

Mr. Mark Stirrup said that some mining engineers thought that it would be useless to place apparatus in mines because of the vibration caused by the workings.

Mr. Symons said that fortunately no difficulty would arise from that cause, as the instruments, though extremely delicate, were not sensitive to vibrations of short period.

Mr. Kenward thought that he knew of a colliery in which instruments could be placed.

SECTION C.

Mr. A. S. Reid said he had been asked by the Sectional Committee to make some remarks. The Underground Waters Committee would present their final Report next year, and would be glad to receive further information up to the date of publication. The Geological Photographs Committee thought that the size of photographs should be left to the donors. As to the best camera, further comments from practical photographers were invited; also remarks as to the best methods of printing. With regard to publication, negotiations respecting the proposed album of representative photographs were then in progress.

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Mr. Tate enquired, with regard to geological photographs, if small photographs taken with a good lens were not preferred?

Mr. Reid replied that the Committee were ready to receive any good photographs.

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OXFORD.

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The meetings of the Conference of Delegates of the Corresponding Societies were held on Thursday, August 9th, and on Tuesday, August 14th, in the New Examination Schools, at 3·30 p.m.

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At the first Conference (August 9th, 1894) the Corresponding Societies Committee were represented by Professor R. Meldola (Chairman), Professor T. G. Bonny, Sir John Evans, Sir Douglas Galton, Dr. Garson, Mr. J. Hopkinson, Mr. Cuthbert Peek, Sir Rawson Rawson, Mr. G. J. Symons, Mr. W. Topley, Mr. W. Whitaker, and Mr. T. V. Holmes (Secretary).

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At the second Conference (August 14th, 1894) the Corresponding Societies Committee were represented by Professor R. Meldola (Chairman), Dr. Garson, Mr. Hopkinson, Sir Rawson Rawson, Mr. Symons, Rev. Canon Tristram, Mr. Whitaker, and Mr. T. V. Holmes (Secretary).

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SECTION A.

Earth-tremors.—Mr. Davison said that in the last Report of the Earth-tremors Committee there was a description of a bifilar pendulum invented by Mr. Horace Darwin. It had been tried for a year at Birmingham, and in consequence of experi-

ments made there a new form of instrument now exhibited was being constructed. Its cost would be about £60. The local societies were so distributed over the country that most places where it was desirable that one of these instruments should be placed were within the area of one them. Instruments placed on the course of great lines of fault (or dislocation of the strata) would yield results of much value.

Mr. Horace Darwin exhibited and explained the construction and use of the bifilar pendulum. He said it was not affected by the rapid, complicated movements which took place during an earthquake, or by the slight tremors caused by passing carts or trains. The movements which it would measure were such as would make a factory chimney or a vertical post fixed in the ground lean over to one side. Extremely small movements of this kind could be measured and recorded on photographically prepared paper. A full account of the instrument was given in *Nature*, of July 12th, 1894. It is made by the Cambridge Scientific Instrument Company.

Mr. Symons, as Chairman of the Earth-tremors Committee, explained how the work of the Committee had grown and in what direction they needed additional help. In the first place the attention of the Committee had been directed to a solution of the question why certain vibrations were recorded by an instrument which had been placed at the bottom of one of the deep coal-mines of the district of Newcastle-on-Tyne. Instead of a straight line a series of pulsations had been obtained. They were traced to two causes—one the gradual settlement of the ground in consequence of the removal of the coal, the other the beating of the waves on the coast.* They had since been looking for traces of earthquake-tremors. Mr. Davison, on one occasion, watched his instrument for some time, as he found pulsations were taking place. These pulsations eventually turned out to have been produced by the earthquake then going on in Greece. They wanted information as to the changes going on in connexion with the faults in geological strata, and, if possible, to get records of the alterations in the earth's crust caused by tidal waves. When the ocean was piled up at one part of the earth's surface it was quite possible that the elastic surface of the earth bent slightly under it. Observations of that kind should be made at more than one station. The work was now going on at Birmingham under Mr. Davison, but they hoped that the Association would give them a grant for a second instrument. They wished to make sure that they were recording, not merely local phenomena, but the great general phenomena of the earth's crust. He was glad to be able to record that one instrument had been established at an observatory south of Biarritz by Mr. Antoine d'Abbadie, who had kindly presented a duplicate instrument to the new observatory at Edinburgh. They were anxious to see two or three instruments of this kind established in different parts of the British Isles, and hoped that some of the wealthy friends of the societies represented at that Conference might co-operate in finding the money for the instruments.

Mr. Tiddeman asked whether the instrument could be placed in an ordinary house, or whether it required a special place in a separate building?

Mr. Symons replied that Mr. Davison had placed it on the cellar floor. A separate building might be preferable, but was more expensive.

Mr. Mills did not think the instrument would be of much use to persons without a special knowledge of it.

Mr. Symons remarked that Mr. Darwin had undertaken to give all the necessary information, and so had Mr. Davison.

In answer to a question from Mr. Mills, he added that it was not essential that an instrument should be placed in a mining district, but it was desirable that they should be scattered throughout the country.

* *Trans. N.E. Inst.*, vol. xxxviii., page 55.

Mr. Seward said that he would try to get one placed in one of the deep mines of South Wales.

The Chairman hoped that by next year some of the Corresponding Societies would have something to report on this question. Mr. Darwin had kindly offered to explain, after the termination of the Conference, the mechanical details to any persons interested.

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SECTION C.

Mr. Whitaker (representing Section C) said that the . . . . other subject was the "Circulation of Underground Waters." The Committee dealing with this matter should have ceased to exist this year, but the final report would not appear till next year. In this case also the local societies would be able to continue the investigation. He took the opportunity of telling the representatvies of the Corresponding Societies that they wanted records of wells and borings, the nature of the beds passed through, and the exact site; also the water-levels and the effects of pumping on them, the temperature, an analysis of the water, and any other useful information. It was suggested that the twenty reports of the Committee should be published, but in that case the information about any particular district would be scattered through several of these reports. But the Committee thought that if these reports were arranged topographically, and possibly condensed, many local societies would be glad to possess the volume. He hoped the local societies would be able to encourage the Committee in the publication of the work by subscribing for a copy of it. It would probably form a book of 250 to 300 pages, and the cost would not exceed 10s.

Mr. Slater said that water had been obtained from a deep well at Malton but the Local Government Board had objected to its quality. They were trying to adopt the remedies suggested, and when a report was issued he would hand it to Mr. Whitaker.

Mr. Holgate remarked that in the neighbourhood of Leeds they had Coal-measures, and had found a different kind of water at each level. This was the case throughout the coal-basin.

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Prof. Blake said that . . . . for the past three years he had published a book (*Annals of British Geology*) which contained abstracts of the geological papers read before the local as well as the London societies. It had not hitherto been self-supporting, though the loss was decreasing. He had failed to get a grant from the British Association, and could no longer afford to publish at a loss, so, though the manuscript for the fourth volume was ready, he could not publish it unless he received additional promises of support. As this state of things was, in all probability, unknown to most of the local societies and their representatives, he had taken this opportunity of mentioning it.

Mr. Whitaker trusted Mr. Blake's remarks would cause an increased sale to that most useful work, the *Annals of British Geology*.

Geological Photographs.—Mr. Jeffs stated that they had received 1,055 photographs. Some districts were totally unrepresented, possibly from want of photographers. The Geological Photographs Committee had passed a resolution recommending the Council of the British Association, whose property the collection was, to deposit it in the Museum of Practical Geology, Jermyn Street, London. As to the question of publication, they had not yet found a publisher who would take the matter up.

The Rev. H. H. Winwood had found great difficulty in getting an amateur to photograph geological sections. Professional men were sometimes worse.

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THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1894–95.

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	W. W. Martin, Royal Literary and Scientific Institution, Bath	100	5s.	10s.	Proceedings, annually.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	257	None	£1 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C.	Museum, College Square. F. J. Bigger, M.R.I.A.	480	None	5s.	Report and Proceedings, annually.
Berwickshire Naturalists' Club, 1831	Berwicksh. Nat. Club	Dr. J. Hardy, Old Cambus, Cockburnspath, N.B.	400	10s. 6d.	6s. to 7s. 6d.	History of the Berwickshire Naturalists' Club, annually.
Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.	W. P. Marshall, Mason College, Birmingham	266	None	£1 1s.	Journal, monthly; Proceedings, annually.
Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	University College, Bristol. H. Percy Leonard	196	5s.	10s.	Proceedings, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	J. G. Wells, Selwood House, Shobnall Street, Burton-on-Trent	242	None	5s.	Annual Report. Transactions, occasionally.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	Walter Cook, 98, St. Mary Street, Cardiff	450	None	10s. 6d.	Transactions, half-yearly.
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. R. Griffith	650	None	5s.	Annual Report. Proceedings, occasionally.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. W. F. Howard, 15, Cavendish Street, Chesterfield	310	£1 1s. None	Members, 31s. 6d.; Associates and Students, 20s.	"Transactions of The Federated Institution of Mining Engineers," about every two months.
Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	365	10s. 6d.	Minimum, 10s. 6d.	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	G. B. Millett, Penzance	100	None	£1 1s.	Report and Transactions, annually.
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C.	Public Hall, Croydon. T. D. Aldous	250	None	10s.	Proceedings and Transactions, annually.
Cumberland and Westmorland Association for the Advancement of Literature and Science, 1876	Cumb. West. Assoc.	J. B. Bailey, 28, Eaglesfield Street, Maryport	500	None	6s.	Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	N. M. Richardson, Montevideo, Chickerel, Weymouth	330	None	10s.	Proceedings, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dr. E. J. Chinnock, Grey Friars', Dumfries	184	2s. 6d.	5s.	Transactions and Journal of Proceedings, annually.
East Kent Natural History Society, 1857	E. Kent N. H. Soc.	19, Watling Street, Canterbury. Frank Baker	87	None	10s. 6d.	"South Eastern Naturalist," occasionally.
East of Scotland Union of Naturalists' Societies, 1884	E. Scot. Union	William D. Sang, 28, Whyte's Causeway, Kirkcaldy, N.B.	10 Societies 982 Membs.	None	Assessment of 4d. per member	Proceedings, generally annually.
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	H. M. Cadell, 5, St. Andrew Square, Edinburgh	237	10s. 6d.	12s. 6d.	Transactions, annually.
Essex Field Club, 1880	Essex F. C.	William Cole, 7, Knighton Villas, Buckhurst Hill, Essex	400	10s. 6d.	15s.	"Essex Naturalist," monthly.
Federated Institution of Mining Engineers	Fed. Inst. Min. Eng.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	2,200	None	None	Transactions, about every two months.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1894-95.—*Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Glasgow Archæological Society, 1856	Glasgow Arch. Soc. ..	207, Bath Street, Glasgow, J. Dalrymple Duncan and W. G. Black	313	None	12s. 6d.	Transactions, annually.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc. ..	J. B. Murdoch, Capelrig, Mearns, Glasgow	250	None	10s.	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc. ..	R. S. Wishart, M.A., and John Cairns, Jun., 207, Bath Street, Glasgow	300	7s. 6d.	7s. 6d.	Proceedings and Transactions, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc. ..	John Mayer, 207, Bath Street, Glasgow	675	£1 1s.	£1 1s.	Proceedings, annually; occasional papers.
Hampshire Field Club, 1885	Hants. F. C.	Hartley Institution, Southampton. W. Dale, F.G.S.	250	None	7s. 6d.	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts. N. H. Soc. ..	John Hopkinson, F.L.S., The Grange, St. Albans	268	10s.	10s.	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C. ..	A. J. Crosfield, Carr End, Reigate	87	10s.	10s.	Proceedings, every two or three years.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc. .	J. Moran, Free Library Buildings, Inverness	170	None	5s.	Transactions, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland ..	W. Lawson, 35, Molesworth Street, Dublin	90	None	£1.	Journal, annually.
Leeds Geological Association, 1874 ..	Leeds Geol. Assoc. ..	Mechanics' Institution. Wm. Lower Carter, F.G.S	141	None	5s.	Transactions, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	80, Municipal Buildings, Leeds. H. B Wilson	179	None	6s.	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	J. M. Gimson, Town Museum, Leicester	312 Members & Associates.	None	Members, £1 1s.; Associates, 10s. 6d.	Transactions, quarterly.
Liverpool Engineering Society, 1875..	Liv'pool E. Soc.	R. C. F. Annett, Royal Institution, Liverpool	251	None	Resident, £1 1s.; Non-res., and Students, 10s. 6d.	Transactions, annually.
Liverpool Geological Society, 1858 ..	Liv'pool Geol. Soc ..	Royal Institution. H. C. Beasley	48	None	£1 1s.	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit Phil. Soc...	Royal Institution. J. M. McMaster	182	None	£1 1s.	Proceedings, annually.
Liverpool Microscopical Society, 1868	Liv'pool Mic. Soc. ..	Royal Institution. Andrew T. Smith, jun.	105	£1 1s.	10s. 6d.	Report, annually.
Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc...	Thomas J. Blanche, Yorkersgate, Malton, Yorkshire	84	None	5s.	Naturalists' Notes, monthly.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Hillside, Ramsey, Isle of Man	140	2s. 6d.	Gentlemen, 6s.; Ladies, 3s.	Yn Lioar Manninagh, quarterly.
Manchester Geographical Society, 1885	Manch. Geog. Soc. ..	Eli Sowerbutts, F.R.G.S., 44, Brown Street, Manchester	850	None	Members, £1 1s.; Associates, 10s. 6d.	Journal, quarterly
Manchester Geological Society, 1838..	Manch. Geol. Soc. ..	James Tonge, 36, George Street, Manchester	200	None	£1.	Transactions, eight or nine parts per annum.
Manchester Statistical Society, 1833 ..	Manch. Stat. Soc. ..	63, Brown Street, Manchester. Francis E. M. Beardsall and T. Gregory	170	10s. 6d.	10s. 6d.	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlb. Coll. N. H. Soc.	Marlborough College. E. Meyrick ..	300	1s. 6d.	3s. and 5s.	Report, annually.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1894–95.—*Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Midland Union of Natural History Societies, 1877	Mid. Union	T. V. Hodgson, 15, Lordswood Road, Harborne, Birmingham	13 Societies, 1,400 Membs.	—	3d. and 1d. per Member	"Midland Naturalist," monthly.
Norfolk and Norwich Naturalists' Society, 1869	Norf. Norw. Nat. Soc.	W. A. Nicholson, 3, Oxford Street, Norwich	266	None	5s.	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	900	None	21s. and 42s.	"Transactions of The Federated Institution of Mining Engineers," about every two months.
North Staffordshire Naturalists' Field Club and Archæological Society, 1865	N. Staff. N. F. C. A. Soc.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.	411	5s.	5s.	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	N'ton N. H. Soc. ..	H. N. Dixon, East Park Parade, Northampton	230	None	10s.	Journal, quarterly.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Nottingham Institute, 9, Shakespeare Street. F. R. Jackson	140	None	5s.	Transactions and Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst. ..	J. Gardner, 3, County Place, Paisley	372	5s.	7s. 6d.	Report, annually.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc. ..	G. F. Tregelles, 3, Market Place, Penzance	82	None	10s. 6d.	Report and Transactions, annually.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci. ..	Tay Street, Perth. S. T. Ellison ..	295	2s. 6d.	5s. 6d.	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, B.Sc., 20, King Street South, Rochdale	249	None	6s.	Transactions, biennially.
Rochester Naturalists' Club, 1878 ..	Rochester N. C.	John Hepworth, Union Street, Rochester	160	None	5s. and 10s.	"Rochester Naturalist," quarterly.
Somersetshire Archæological and Natural History Club, 1849	Som'setsh. A.N.H. Soc.	The Castle, Taunton. F. T. Elworthy	552	10s. 6d.	10s. 6d.	Proceedings, annually.
South African Philosophical Society, 1877	S. African Phil. Soc. ..	W. H. Finlay, Royal Observatory, Cape Town	68	None	£2.	Transactions, annually.
South London Microscopical and Natural History Club, 1871	S. London M. N. H. C...	Brixton Hall, Acre Lane, Brixton. H. Groves	100	None	10s.	Report, annually.
Tyneside Geographical Society, 1887 ..	Tyneside Geog. Soc. ..	Geographical Institute, Barras Bridge, Newcastle-upon-Tyne. G. E. T. Smithson	1,000	None	10s.	Journal, half-yearly.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C. ..	W. G. Fretton, F.S.A., Hearsall Terrace, Chapel Fields, Coventry	84	2s. 6d.	5s.	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C. ..	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	204	10s.	10s.	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Wm. Lower Carter, F.G.S., Hopton, Mirfield	160	None	13s.	Proceedings, annually.
Yorkshire Naturalists' Union, 1861 ..	Yorks. Nat. Union ..	W. Denison Roebuck, F.L.S., Sunny Bank, Leeds	460 and 2,500 Associates	None	10s. 6d.	Transactions, annually; "The Naturalist," monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc. ..	Museum, York. T. S. Noble, F.G.S.	360	None	£2.	Report, annually.

INDEX OF THE MORE IMPORTANT PAPERS, AND ESPECIALLY THOSE REFERRING TO LOCAL SCIENTIFIC INVESTIGATIONS, PUBLISHED BY THE ABOVE-NAMED SOCIETIES DURING THE YEAR ENDING JUNE 1, 1894.*

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Aitken, W.	On Special Applications of the Telephone	Glasgow Phil. Soc.	*Proc.*	XXIV.	184	1893
Henderson, J.	Rapid Traverser	Fed. Inst. Min. Eng.	*Trans.*	5	199	"
Jamieson, A.	Comparative Tests of Hellesen and E.C.C. Dry Battery Cells	Glasgow Phil. Soc.	*Proc.*	XXIV.	89	"
Meikle, A.	Lord Kelvin's new Electricity Meters	" "	"	"	170	"
Murray, W. F.	On a new System of Firing Pottery Ware by the use of Gaseous Fuel	"	"		64	"
Stroud, Prof. H.	Magnetic Declination and its Variations	N. Eng. Inst.	*Trans. Fed. Inst.*	7	268	1894
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Section B.—CHEMISTRY.

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Bedson, Prof. P. P.	A Contribution to our Knowledge of Coal-dust: Part II.	N. Eng. Inst.	*Trans. Fed. Inst.*	7	27	1894
Bedson, Prof. P. P., and J. W. McConnell	A Contribution to our Knowledge of Coal-dust: Part III.	" "	" "	"	32	"
Blackett, W. C.	The Combustion of Oxygen and Coal-dust in Mines	" "	" "	"	54	"
Clowes, Prof. F.	The Hydrogen-oil Gas-testing Safety-lamp	Ch'sterf. Mid. Count. Inst	" "	"	2	"
Gresley, W. S.	Spontaneous Combustion in Coal-mines	Fed. Inst. Min. Eng.	*Trans.*	"	206	"
"	Notes on Outbursts of Soft Coal and Gas	Manch. Geol. Soc.	"	XXII.	429	1893
Kayll, A. C.	Mining Explosives: their Definition as Authorized under the Explosives Act (1875)	N. Eng. Inst.	*Trans. Fed. Inst.*	6	346	"
Neate, P. J.	Aluminium	Rochester N. C.	*Roch. Naturalist*	II.	177	"
Settle, J.	Spontaneous Combustion in Coal-mines	Fed. Inst. Min. Eng.	*Trans.*	5	10	"
Stokes, A. H.	A Safety-lamp with Standard Alcohol-flame Adjustment, for the Detection and Elimination of Small Percentages of Inflammable Gas	Chesterf. Mid. Count. Inst.	*Trans. Fed. Inst.*	"	462	"
Tilden, Prof. W. A.	Early Iron Working in the Highlands of Scotland	Birm. N. H. Phil. Soc.	*Proc.*	IX.	48	1894
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* The Titles of Papers on other than Mining and Mechanical Engineering, etc., have not been reprinted.

Section C.—Geology.

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Aitken, H.	The Hilderston Silver Mine near Linlithgow	Fed. Inst. Min. Eng.	*Trans.*	6	193	1893
" "	The Formation of the Earth's Crust and its Destruction	" "	"	"	210	"
Banks, R. W.	Reminiscences of the Downton Sandstone	Woolhope N. F. C.	"	1890-92.	390	1894
Bertrand, M.	The Correlation of the Coal-fields of Northern France and Southern England	Fed. Inst. Min. Eng.	"	5	106	1893
Blackwell, G. G.	Notes on Bauxite of Co. Antrim, and its Uses in the Manufacture	Manch. Geol. Soc.	"	XXII.	525	1894
Brodie, Rev. P. B.	Notice of a Section in the Lower Lias at the Cement Works near Rugby	Warw. N. A. F. C.	*Proc.*	38	17	"
" "	Remarks on a Section in supposed Drift at Hillmorton, near Rugby	" "	"	"	37	"
" "	Notice of a Section in the Middle Lias at Napton	" "	"	"	43	"
" "	On Additional Remains of Cestraciont and other Fish in the Green Marls immediately overlying the Red Marls of the Upper Keuper in Warwickshire; with an account of the equivalent Beds in Germany and the Tyrol	" "	"	"	48	"
Browne, M.	A Contribution to the History of the Geology of the Borough of Leicester	Leicester Lit. Phil. Soc.	*Trans.*	III.	123	1893
Buckman, S. S.	The Top of the Inferior Oolite and a Correlation of Inferior Oolite Deposits	Dorset N. H. A. F. C.	*Proc.*	XIV.	37	"
Cadell, H. M.	The Geological Changes wrought by Man within the Forth Basin	Edinb. Geol. Soc.	*Trans.*	VI.	275	"
" "	The Old Lakes of Edinburgh	" "	"	"	287	"
Cameron, A. C. G.	The Geology, Mining, and Economic Uses of Fuller's Earth	Fed. Inst. Min. Eng.	"	6	204	"
Collins, A. L.	The Ghorband Lead Mines, Afghanistan	N. Eng. Inst.	*Trans. Fed. Inst.*	"	494	"
Collins, J. H.	Illustrations of Cornish Fossils	Cornw. R. Geol. Soc.	*Trans.*	XI.	563	1894
Cornewall, Rev. Sir G. H.	The Formation of Travertine	Woolhope N. F. C.	"	1890-92.	238	"
Cumming, L.	Some Observations on Mountain Débris	Liverpool Geol. Soc.	*Proc.*	VII.	87	1893
Cuttriss, S. W.	The Parallel Roads of Glen Roy	Leeds Geol. Assoc.	*Trans.*	VIII.	24	"
Dakyns, J. R.	A Sketch of the Geology of Nidderdale and the Washburn North of Blubberhouses	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	294	1894
" "	The Glacial Phenomena of Wharfedale between Bolton Abbey and Kettlewell	" "	"	"	299	"
Dawkins, Prof. W. Boyd	Geology in Relation to Geography	Manch. Geol. Soc.	*Journal*	VIII.	226	1893
"	On the South-Eastern Coal-field at Dover	" "	*Trans.*	XXII.	488	1894
De Rance, C. E.	On the Boring for Coal on the Freeholders' Estate at Hazel Grove	" "	"	"	452	"
Dickson, E.	Note on Section at Skillaw Clough, near Parbold	Liv'pool Geol. Soc.	*Proc.*	VII.	106	1893
Enys, J. D.	On the Action of Wind and Sand in Cutting Stone	Cornw. R. Geol. Soc.	*Trans.*	XI.	533	1894
Farrar, A.	The Coast between Eastbourne and Folkestone	Leeds Geol. Assoc.	"	VIII.	48	1893
Forsyth, Dr. D.	The General Geology of Scotland	" "	"	"	34	"
Fox-Strangways, C.	The Valleys of North-East Yorkshire and their Mode of Formation	Leicester Lit. Phil. Soc.	"	III.	333	1894
Geikie, Sir A.	The Work of the Geological Survey	Fed. Inst. Min. Eng.	"	5	142	1893
Gibson, W.	Geology of the Southern Transvaal	" "	"	6	124	"
Goodchild, J. G.	The Minerals at Barnton	Edinb. Geol. Soc.	"	VI.	301	"
Greenwell, G. C., Jun.	Bitumen from a Coal-seam at Poynton, near Stockport	Manch. Geog. Soc.	"	XXII.	444	1894
Halse, E.	The Gold-bearing Veins of the Organos District, Tolima, U.S. Colombia	N. Eng. Inst.	*Trans. Fed. Inst.*	5	233	1893
"	Note on the Occurrence of Mercury at Quindiú, Tolima, U.S. Colombia	" "	" "	6	59	"
"	Note on the Antimony Deposit of El Altar, Sonora, Mexico	" "	" "	"	290	"
Hardcastle, C. D.	Chalk and Flint	Leeds Geol. Assoc.	*Trans.*	VIII.	14	"
Harker, A.	Bibliography of Geology and Palæontology for the North of England, 1892	Yorks. Nat. Union	*The Naturalist*	For 1893	265	"
Hawkesworth, E.	Notes on Some Withernsea Specimens	Leeds Geol. Assoc.	*Trans.*	VIII.	52	"
Heath, A. J., and C. L. Morgan	On the Fish Remains of the Lower Carboniferous Rocks of the Bristol District	Bristol Nat. Soc.	*Proc.*	VII.	80	"
Henderson, J.	Sections Exposed on the Barnton Railway	Edinb. Geol. Soc.	*Trans.*	VI.	297	"

Section C.—GEOLOGY.—*Continued.*

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Hewitt, W.	The Physical Conditions of the Aralo-Caspian Region as bearing on the Conditions under which the Triassic Rocks were Formed	Liv'pool Geol. Soc.	*Proc.*	VII.	11	1893
Holgate, B.	Some Examples of Change in Rock caused by the Permeation of Underground Water	Leeds Geol. Assoc.	*Trans.*	VIII.	73	"
Holland, P., and E. Dickson	Remarks on the Formation of Clay	Liv'pool Geol. Soc.	*Proc.*	VII.	108	"
Holmes, W. M.	On the Microscopic Structure of Hearthstone from Betchworth, Surrey	Croydon M. N. H. C.	*Trans.*	For 1892-93	17	"
Howard, F. T.	Note on the Effect of Fire on Bath Oolite	Cardiff Nat. Soc.	"	{XXV. Pt. II.}	43	1894
" "	On an Ichthyosaurus found at Penarth	" "	"		44	"
Hughes, Prof. T. McK.	Observations on the Silurian Rocks of North Wales	Chester Soc. Nat. Sci.	*Proc.*	IV.	141	"
Ingleby, J.	Corals and Coral Islands	Leeds Geol. Assoc.	*Trans.*	VIII.	9	1893
Johnston-Lavis, Dr. H. J.	The Ejected Blocks of Mount Somma	Edinb. Geol. Soc.	"	VI.	314	"
Kendall, P. F.	The Cause of the Ice Age	Leeds Geol. Assoc.	"	VIII.	53	"
" "	The Glaciation of Yorkshire	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	275	1894
Kinahan, G. H.	On the Iron Ore Measures of County Antrim	Manch. Geol. Soc.	*Trans.*	XXII.	458	"
" "	On Boulder Clay Nodules and Ice-worn Stones	"	"	"	512	"
Kirkup, J. P.	Singareni Coal-field, Hyderabad, India	N. Eng. Inst.	*Trans. Fed. Inst.*	6	421	1893
La Touche, Rev. J. D.	Notes on the Asteroidea or Star Fishes of Church Hill Quarry, etc.	Woolhope N. F. C.	*Trans.*	1890-92	35	1894
" "	The Passage or Transition Beds	" "	"	"	37	"
" "	The Geology of the Woolhope District	" "	"	"	160	"
" "	Igneous Rocks, and the Eruption of Diorite at Bartestree	" "	"	"	166	"
Lea, Rev. T. S.	The Physiography and Geology of the Dingle of Sapey Brook	" "	"	"	306	"
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Lupton, A.	Geology of the West Yorkshire Coal-field	Fed. Inst. Min. Eng.	*Trans.*	7	137	1894
Mansel-Pleydell, J. C.	Presidential Address: Palæobotany	Dorset N. H. A. F. C.	*Proc.*	XIV.	1	1893
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Miall, Prof. L. C.	The Distribution of Plants and Animals as affected by the past History of the Earth	Leeds Geol. Assoc.	*Trans.*	VIII.	74	"
Milne, J.	On Earth Pulsations and Mine Gas	Fed. Inst. Min. Eng.	"	5	203	"
Monckton, H. W.	Geological Notes in the Neighbourhood of Ongar, Essex	Essex F. C.	*Essex Naturalist*	VII.	87	"
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Moore, A. G.	Notes of a Mining Engineer's Visit to South Africa	" "	" "	"	190	"
Moore, R. T.	Recent Developments of the Hamilton Coal-field	Glasgow Phil. Soc.	*Proc.*	XXIV.	51	"
Morris, T.	Geological, Manufacturing, and other Notes on Iron	Liv'pool E. Soc.	*Trans.*	XIV.	84	"
Overend, J.	The Coal-fields of Sonora, Mexico	Fed. Inst. Min. Eng.	"	7	230	1894
Peach, B. N., & J. Horne	On a Shelly Mound at Tongue Ferry, Sutherland	Edinb. Geol. Soc.	"	VI.	303	1893
" "	The Occurrence of Shelly Boulder Clay in North Ronaldshay, Orkney	" "	"	"	309	"
Pelle, W.	Notes and Analyses of Iron Ores and Bauxite from the Crommelin Mines, Co. Antrim	Manch. Geol. Soc.	"	XXII.	522	1894
Piper, G. H.	Further Remarks on the Physical Geology of the Woolhope Valley	Woolhope N. F. C.	"	1890-92	164	"
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Platnauer, H. M.	Notes on Borings near York	Yorks. Phil. Soc.	*Report*	For 1893	56	1894
Reade, T. M.	The Drift Beds of the Moel Tryfaen Area of the North Wales Coast	Liv'pool Geol. Soc.	*Proc.*	VII.	36	1893
Richards, E. P.	On Researches in the newly-discovered "Acrodias Bed" in the Green Gritty Marls of the Upper Keuper at Shrewley, Warwickshire; chiefly upon its Extension	Warw. N. A. F. C.	,,	38	54	1894
Ricketts, Dr. C.	On some Conditions existing during the Formation of the Older Carboniferous Rocks	Liv'pool Geol. Soc.	,,	VII.	94	1893
Shaw, F. G.	Auriferous Conglomerates of Witwatersrandt	Fed. Inst. Min. Eng.	*Trans.*	5	169	,,
Shone, W.	Subterranean Erosion, and some of its Effects	Chester Soc. Nat. Sci.	*Proc.*	IV.	252	1894
,,	The Cause of Crateriform Sand Dunes and Cwms	,, ,,	,,	,,	263	,,
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Somervail, A.	The Origin and Relations of the Lizard Rocks	Cornw. R. Geol. Soc.	*Trans.*	XI.	536	,,
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Stirrup, M.	Further Notes on Boulders from the Coal-measures	Manch. Geol. Soc.	,,	XXII.	321	1893
Tate, T.	Lake Country Rocks Microscopically described	Yorks. Nat. Union	*The Naturalist*	For 1893	247	,,
Teall, J. J. H.	On Greenstones associated with Radiolarian Cherts	Corn. R. Geol. Soc.	*Trans.*	XI.	560	1894
Thompson, B.	Geological Notes	N'ton N. H. Soc.	*Journal*	VII.	254	1893
Watson, C. J.	The Hemlock Stone	Birm. N. H. Phil. Soc.	,,	I.	29	1894
Watts, W.	Singular Nodules and Ice-worn Stones found in the Boulder Clay of Piethorn Valley	Manch. Geol. Soc.	*Trans.*	XXII.	436	1893
Williams, C. H.	Practical Notes on the Mining of Iron Ores, Bauxite, etc., of Co. Antrim	,, ,,	,, ,,	,,	518	,,
Wilson, A. P.	Minerals and Mining in Tasmania	N. Eng. Inst.	*Trans. Fed. Inst.*	7	276	,,
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Section D.—BIOLOGY.

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Section E.—GEOGRAPHY.

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Dawkins, Prof. W. Boyd	Geology in Relation to Geography	Manch. Geog. Soc.	*Journal*	VIII.	226	1893
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Section F.—ECONOMIC SCIENCE AND STATISTICS.

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Binns, G. J.	Mining in New Zealand: Part III. Coal-mining	Fed. Inst. Min. Eng.	*Trans.*	5	31	1893
Chesneau, G.	The Oil Shale Industry of France	" "	"	7	180	1894
Fogg, W.	Strikes and Economic Fallacies	Manch. Stat. Soc.	"	1893-94.	1	"
Hoskold, H. D.	Notes upon a Practical Method of ascertaining the Value or Price to be paid for Zinc	Fed. Inst. Min. Eng.	"	{ 5 7	93 222	1893 1894
Lewis, G.	Presidential Address	" "	"	5	2	1893
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Morison, J.	Limestone Mining in Scotland	" "	"	6	199	1893
Steavenson, A. L.	Presidential Address	N. Eng. Inst.	*Trans. Fed. Inst.*	"	273	1894
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Section G.—MECHANICAL SCIENCE.

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Barnes, A.	Presidential Address	Chesterf. Mid. Count. In.	*Trans. Fed. Inst.*	5	457	1893
Baum, F.	The Baum Coal-washing Machinery	Fed. Inst. Min. Eng.	" "	7	156	1894
Capell, Rev. G. M.	Manometric Efficiency of Fans	N. Eng. Inst.	" "	5	212	1893
Charleton, A. G.	The Choice of Coarse and Fine Crushing Machinery and Processes of Ore-Treatment:					
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	Part IV. Gold	" "	" "	6	69	"
	Part V. Gold Milling	" "	" "	"	295	"
	Part VI. Gold Milling	" "	" "	"	457	"
	Part VII. Medium, Coarse, and Fine Crushing Stamps	" "	" "	7	67	1894
Collins, A. L.	Fire-setting: the Art of Mining by Fire	Fed. Inst. Min. Eng.	*Trans.*	5	82	1893
Conradi, J. F.	Description of Petroleum Engine, with Tests	Liv'pool E. Soc.	"	XIV.	103	"
Deacon, G. F.	A Sketch of the Vyrnwy Works	" "	"	"	49	"
Farren, G.	On Forces used by Engineers considered as Velocities	" "	"	"	138	"
Fitzgerald, Prof. M. F.	Electric Power Supply on Tramways at Patterson, New Jersey	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1892-93	81	1894
Fox, F.	Local Engineering Works in progress or contemplated	Bristol Nat. Soc.	*Proc.*	VII.	103	1893
Goodman, Prof.	The Transmission of Power by Compressed Air	Fed. Inst. Min. Eng.	*Trans.*	7	233	1894
Greenhill, J. H.	Electricity as an Illuminant	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1892-93	19	"
Harvey, J. W. I.	Draught in Marine Boilers	Bristol Nat. Soc.	*Proc.*	VII.	118	1893
Hele-Shaw, Prof. H. S.	The Graphical Method of Solving Engineering Problems	Liv'pool E. Soc.	"	XIV.	173	"
Higson, C. H.	The Walker Indestructible Fan and Engines	Manch. Geol. Soc.	"	XXII.	468	1894
Hughes, H. W.	Photography in Mines	Fed. Inst. Min. Eng.	"	7	164	"
Leach, C. C.	Corliss-engined Fan at Seghill Colliery	N. Eng. Inst.	*Trans.*	6	48	1893
Lynde, J. H.	Automatic Sprinklers	Liv'pool E. Soc.	"	XIV.	125	"
Morris, T.	Geological, Manufacturing, and other Notes on Iron	" "	"	"	84	"
Murgue, D.	The Friction of, or Resistance to, Air-currents in Mines	Fed. Inst. Min. Eng.	"	6	135	"
"	Do. Appendix	" "	"	7	211	1894

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Pierce, E. W.	Engineering Contracts	Liv'pool E. Soc.	*Trans.*	XIV.	212	1893
Saint, W.	On recent Improvements in Mining Machinery and Appliances	Manch. Geol. Soc. ..	"	XXII.	404	"
Seward, E.	Presidential Address: A proposed new Railway Connexion of South Wales and London	Cardiff Nat. Soc. ..	"	XXV. Pt. II.	62	1894
Spencer, W.	The Support of Buildings	Fed. Inst. Min. Eng. ..	"	5	188	1893
Stokes, A. H.	An Improved Water-gauge	Chesterf. Mid. Count. In.	*Trans. Fed. Inst.*	"	474	"
Wordsworth, T.	Notes on Coal-getting by Machinery	Fed. Inst. Min. Eng. ..	*Trans.*	7	149	1894
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Section H.—ANTHROPOLOGY.

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Section I.—PHYSIOLOGY.

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Committees appointed by the General Committee at the Oxford Meeting in August, 1894.

1.—Receiving Grants of Money.

Subject for Investigation or Purpose.	Members of the Committee.	Grants.
Considering the advisability and possibility of establishing in other parts of the country observations upon the prevalence of earth-tremors, similar to those now being made in Durham in connexion with coal-mine explosions.	*Chairman*.—Mr. G. J. Symons. *Secretary*.—Mr. C. Davison. Sir F. J. Bramwell, Prof. G. H. Darwin, Prof. J. A. Ewing, Mr. Isaac Roberts, Mr. T. Gray, Sir J. Evans, Prof. J. Prestwick, Prof. E. Hull, Prof. G. A. Lebour, Prof. R. Meldola, Prof. J. W. Judd, Mr. M. Walton Brown, Mr. J. Glaisher, Prof. C. G. Knott, Prof. J. H. Poynting, and Mr. Horace Darwin.	£ s. d. 75 0 0
To confer with British and foreign societies publishing mathematical and physical papers as to the desirability of securing uniformity in the size of the pages of their Transactions and Proceedings.	*Chairman*.—Prof. S. P. Thompson. *Secretary*.—Mr. J. Swinburne. Mr. G. H. Bryan, Mr. C. V. Burton, Mr. R. T. Glazebrook, Prof. A. W. Rücker, and Dr. G. Johnstone Stoney.	5 0 0
The collection, preservation, and systematic registration of photographs of geological interest. [Last year's grant renewed.]	*Chairman*.—Prof. J. Geikie. *Secretary*.—Mr. O. W. Jeffs. Prof. T. G. Bonney, Prof. Boyd Dawkins, Prof. T. McKenny Hughes, Dr. V. Ball, Dr. T. Anderson, and Messrs. A. S. Reid, E. J. Garwood, W. Gray, H. B. Woodward, J. E. Bedford, R. Kidston, W. W. Watts, R. H. Tiddeman, J. J. H. Teall, and J. G. Goodchild.	10 0 0
To report on methods of calibrating the measuring instruments used in engineering laboratories, and to take steps for comparing the measuring instruments at present in use in different laboratories	*Chairman*.—Prof. A. B. W. Kennedy. *Secretary*.—Prof. W. C. Unwin.	50 0 0
Corresponding Societies Committee	*Chairman*.—Prof. R. Meldola. *Secretary*.—Mr. T. V. Holmes. Mr. Francis Galton, Sir Douglas Galton, Sir Rawson Rawson, Mr. G. J. Symons, Dr. J. G. Garson, Sir John Evans, Mr. J. Hopkinson, Prof. T. G. Bonney, Mr. W. Whitaker, Mr. W. Topley, Prof. E. B. Poulton, Mr. Cuthbert Peek, and Rev. Canon H. B. Tristram.	30 0 0
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2.—Not Receiving Grants of Money.

Subject for Investigation or Purpose.	Members of the Committee.
The rate of increase of underground temperature downwards in various localities of dry land and under water	*Chairman*.—Prof. J. D. Everett. *Secretary*.—Prof. J. D. Everett. Prof. Lord Kelvin, Mr. G. J. Symons, Sir A. Geikie, Mr. J. Glaisher, Prof. Edward Hull, Prof. J. Prestwich, Dr. C. Le Neve Foster, Prof. A. S. Herschel, Prof. G. A. Lebour, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, and Prof. Michie Smith.
To enquire into the proximate chemical constituents of the various kinds of coal.	*Chairman*.—Sir I. Lowthian Bell. *Secretary*.—Prof. P. Phillips Bedson. Prof. F. Clowes, Mr. Ludwig Mond, Profs. Vivian B. Lewes and E. Hull, and Messrs. J. W. Thomas and H. Bauerman.
To consider the best methods for the registration of all type specimens of fossils in the British Isles, and to report on the same.	*Chairman*.—Dr. H. Woodward. *Secretary*.—Mr. A. Smith Woodward. Rev. G. F. Whidborne, Mr. R. Kidston, and Mr. J. E. Marr.
The circulation of the underground waters in the permeable formations of England, and the quality and quantity of the waters supplied to various towns and districts from these formations; and that a digest of the eighteen reports should be prepared by the committee, and sold in a separate form.	*Chairman*.—Prof. E. Hull. *Secretary*.—Mr. C. E. De Rance. Sir D. Galton, Prof. J. Prestwich, and Messrs. J. Glaisher, P. F. Kendall, E. B. Marten, G. H. Morton, I. Roberts, T. S. Stooke, G. J. Symons, W. Topley, C. Tylden-Wright, E. Wethered, and Whitaker.
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EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname.

Discussions are printed in *italics*.

The following contractions are used:—

C.—Chesterfield and Midland Counties Institution of Engineers.
M.—Midland Institute of Mining, Civil, and Mechanical Engineers.
S.—Mining Institute of Scotland.
N.E.—North of England Institute of Mining and Mechanical Engineers.
N.S.—North Staffordshire Institute of Mining and Mechanical Engineers.
S.S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.